Ingenuo magnæque spei
Adolescenti
Thomæ Fitzpatrick
Rei Herbariæ studia
feliciter inchoanti
Præmium hoc literarium dederunt
Præpositus et Socii Seniores Collegii
Sacrosanctæ & Individuæ
Trinitatis juxta Dublin.

Term S.S. Trinitatis A.D. 1854
Quod Testor
Georgius Jacobus Allman
Botanices Professor

Thos. Fitzpatrick, A.B.
Trin. Coll. Dublin.

whose widow gave it to
Norman Moore



# PRINCIPLES

OF

# HUMAN PHYSIOLOGY.

*By the same Author.*

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# PRINCIPLES

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# HUMAN PHYSIOLOGY,

WITH THEIR CHIEF APPLICATIONS TO PSYCHOLOGY, PATHOLOGY, THERAPEUTICS, HYGIÈNE, AND FORENSIC MEDICINE.

BY

WILLIAM B. CARPENTER, M.D., F.R.S., F.G.S.,

EXAMINER IN PHYSIOLOGY AND COMPARATIVE ANATOMY
IN THE UNIVERSITY OF LONDON, PROFESSOR OF MEDICAL JURISPRUDENCE
IN UNIVERSITY COLLEGE,
PRINCIPAL OF UNIVERSITY HALL, ETC.

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TO

# WILLIAM PULTENEY ALISON,

M.D., F.R.S.E. &c.

PROFESSOR OF THE PRACTICE OF MEDICINE OF THE UNIVERSITY OF EDINBURGH.

---

My dear Sir,

I take the liberty of inscribing the following Work to you, as an expression of my grateful remembrance of the value of your instructions, of my respect for those Intellectual faculties which render you pre-eminent amongst the Medical Philosophers of our time, and of my admiration for those Moral excellencies which call forth the warm regard of all who are acquainted with your character.

In many parts of this Treatise, you will find that doctrines, which you have long upheld in opposition to almost the whole Physiological world, are defended with such resources as I could command; and that, in many instances, such convincing evidence of their truth has been afforded by recent observations, that further opposition to them would now seem vain. And if I have presumed to differ from you on some points, it has been in the spirit of that independence, which you have uniformly encouraged in your pupils; yet with a distrust of my own judgment, wherever it came into collision with yours.

That you may long be spared to be the ornament of your University, and the honour of your City, is the earnest wish of,

Dear Sir,

Your obliged Pupil,

WILLIAM B. CARPENTER.

# PREFACE TO THE FOURTH EDITION.

The Author feels it necessary to apologize to those, whose kind appreciation of the following work occasioned a call for a New Edition as much as two years since, to apologize for the delay which has attended its appearance. Having been at that time engaged in re-writing his "Principles of General and Comparative Physiology," he felt that he could not do justice to that work, if he were not to bring it to a conclusion before taking another in hand; and when, on the completion of that task, he applied himself to the preparation of his "Principles of Human Physiology" for the press, he found that nothing short of *an entire remodelling* of the preceding Edition would in any degree satisfy his notions of what such a treatise ought to be. For although no fundamental change had taken place during the interval in the fabric of Physiological Science, yet a large number of less important modifications had been effected, which had combined to produce a very considerable alteration in its aspect. Moreover, the progressive maturation of his own views, and his increased experience as a Teacher, had not only rendered him more keenly alive to the imperfections which were inherent in its original plan, but had caused him to look upon many topics in a light very different from that under which he had previously regarded them; and, in particular, he felt a strong desire to give to his work as *practical* a character as possible, without foregoing the position which (he trusts he may say without presumption) he had succeeded in gaining for it, as a *philosophical* exposition of one important department of Physiological Science. He was led, therefore, to the determination of, in reality, producing *a new treatise*, in which only those parts of the old should be retained, which might express the existing state of knowledge, and of his own opinions, on the points to which they relate: and the following outline of the changes which he has made, will show the extent to which this reconstruction has been accomplished.

Considering it extremely important that his readers should have a

clear idea of the sense in which the terms *Law* and *Cause* are subsequently employed, he has devoted a few pages of the *Introduction* to an explanation of his views upon these points; and he hopes that he may be there found to have thrown some light upon the philosophy of causation, which may be of assistance to other scientific inquirers.

In order to make room for a portion of the new matter which he desired to introduce into the treatise, he has felt it necessary to omit all those references to the structure and vital actions of the lower animals, which had not an immediate and direct bearing upon Human Physiology; and consequently, of the First Chapter of the previous editions—"On the Place of Man in the Scale of Being,"—he has only retained so much as related to the characteristics that distinguish Man from the Mammalia which most nearly approach him. The succeeding Chapter, which treated "Of the Different Branches of the Human Family and their Mutual Relations," has been extended in all that relates to Man, and curtailed in that which rather belongs to Comparative Physiology; and has been transferred to nearly the end of the volume, which the Author considers to be now the more appropriate place for it.

The Second Chapter of the present Edition, comprising a general view "Of the Chemical Components of the Human Body, and the Changes which they undergo within it," is now for the first time introduced. The Author has aimed to render it as complete as its necessary limits would permit; and hopes that he will be found not to have omitted anything truly important, and to have presented a faithful, though concise, exposition of the present state of our knowledge upon this important subject. In the preparation of this Chapter, he has made great use of the admirable "Physiological Chemistry" of Prof. Lehmann, now in progress of translation by Prof. Day for the Cavendish Society; and not only this, but other portions of his work that involve a scientific knowledge of Organic Chemistry, have had the advantage of Prof. Day's revision,—a service for which the Author feels greatly indebted, both for himself, and in behalf of his readers. Several new views will be found in this Chapter, which have occurred to the Author during its preparation; he would especially point to that of the respective relations of Fibrin and Albumen to the nutritive processes, and of the former to the Gelatinous tissues (§§ 29, 30); and to the General Summary which forms the last section, in which the discoveries of M. Cl. Bernard in regard to the elaboration of sugar and fat in the Liver, are placed (he believes) in a somewhat novel aspect.

From the consideration of the chemical components of the organism, and of the participation of chemical forces in its operations, it seemed natural to pass-on to that of "The Structural Elements of the Human

Body, and the Vital Actions which they exhibit," which forms the subject of the Third Chapter. Nearly the whole of this Chapter, which includes the general doctrines of Cell-formation and of Vital Force, in their application to Human Physiology, appears for the first time in this edition.

Passing on to the more detailed survey of the constituent parts of the Human body, the first place seemed to be claimed by the Blood; the "Physical Characters, Chemical Composition, and Vital Properties" of which are treated-of at some length in Chapter IV. This portion has been greatly extended, and almost entirely re-written; the great importance of the subject, in its bearings on Pathology as well as on Physiology, having been constantly kept in view. The Author does not profess to have included by any means all that might have been brought together on the subject; but he has selected those facts with which he considered it most important that his readers should be acquainted, and those doctrines which seemed to him to have the most direct practical applications. As original contributions to this department of Physiology, he would especially point to the correction (§ 154) of the ordinary analyses of the Blood (the essential point of which, he may remark, has been brought under the notice of the French Academy by M. Lecanu, some months since this chapter passed through the press); and to the account of that state of the blood which gives a special predisposition to zymotic disease (§ 210), — a doctrine, which, although to a certain extent hypothetical, will be found (he believes) to be in such strict accordance with all the known facts bearing upon the subject, as to be almost entitled to rank as a legitimate generalization of them.

The Fifth Chapter, "On the Primary Tissues of the Living Body; their Structure, Composition, and Actions," is essentially the same with the Third Chapter of the previous Edition; but a large amount of new matter, in great part supplied by the elaborate "Mikroscopische Anatomie" of Prof. Kölliker, has been incorporated in it; and many new illustrations, chiefly derived from the same source, have been introduced. The account of the vital endowments of the Muscular and Nervous tissues, previously contained in other chapters, has been transferred to this; so as to make it embody a complete sketch of those physiological actions of the separate parts of the organism, which are afterwards to be considered in their relations to each other.

This Chapter is followed, as in the previous Edition, by a "General View of the Functions of the Human Body" (CHAP. VI.), in which there has been but little alteration.

In conformity with the opinion expressed by some of his friendly Critics, and by many Teachers of Physiology, the Author has reversed

the previous arrangement of the Chapters which treat of the Functions in detail; those relating to the Organic Functions being now placed *before* those in which the Animal Functions are described, instead of *after*. This has involved a new distribution of much of the matter which was previously treated in a connected form in the Chapter on the "Functions of the Nervous System;" since it has appeared to the Author very desirable that the whole group of actions whose aggregate makes up each function, should now be considered in its connexion; and thus the movements of Deglutition, Respiration, &c., not having been explained (as was formerly the case) in the earlier part of the volume, are described, and their connection with the Nervous System examined, under each separate head. Their general relations to the Nervous System having been previously explained, however, in the Sixth Chapter, the Author does not apprehend that any inconvenience will be experienced from this alteration.—By the adoption of this change, in some degree against his own judgment, the Author trusts that he has sufficiently marked his desire to profit by all such advice as may be tendered to him in a friendly spirit, and by those whose position or attainments give value to their opinion.

The series of Chapters on the several Organic Functions, remain essentially the same as in the previous Edition; but important additions and corrections have been made in every one. Thus, in Chapter VII. "On Food and the Digestive Process," the whole subject of Food is much more fully discussed than heretofore; and the most important of the results obtained from the study of the Digestive Process by Frerichs, Bernard, and other experimenters, have been embodied in the account of it. In Chapter VIII., "On Absorption and Sanguification," the structure and development of the Ductless Glands have been more fully described, in accordance with the researches of Kölliker, Sanders, Ecker, Gray, and others; and their relation to the process of Sanguification more clearly elucidated. In Chapter IX. "On the Circulation of the Blood," the causes of the Heart's Sounds have been more fully considered; a view of the nature of its rhythmical contractions has been suggested (§ 498, 499), which the Author believes to be original; and the most important among the results of Prof. Volkmann's elaborate researches on the Dynamics of the Movement of the Blood have been introduced. In Chapter X., "On Respiration," the chief additions to the first Section, are those which embody the results of Dr. Hutchinson's inquiries on the Movements of Respiration; to the second, the data furnished by the researches of MM. Regnault and Reiset, Prof. Scharling, M. Barral, and others, upon the amount of Oxygen absorbed and of Carbonic Acid exhaled; whilst the third, in which the "Effects of Suspension or Deficiency of Respiration" are discussed, has been largely augmented by

a summary of the evidence afforded by our recent experience, of the marked tendency of an habitually-imperfect Respiration to produce a liability to Zymotic disease. Nearly the whole of Chapter XI., "On Nutrition," has been newly written for this Edition; and here, as elsewhere, the Author has been greatly indebted to the Hunterian Lectures of his friend, Mr. Paget, whose contributions to this department of Physiology he regards as of the highest scientific as well as practical value. He cannot forbear, moreover, to express the pleasure which he has derived, from finding that Mr. Paget most fully recognizes, and gives him credit for two important doctrines which he had taught in former editions of this work; namely, the limits to the Duration of individual parts, imposed by the very fact of their independent vitality, and varying with the activity of their vital operations; and the diminished Formative power of the tissues, as one of the essential constituents of the state of Inflammation. In Chapter XII., "On Secretion and Excretion," important additions have been made under almost every head; and those parts, especially, which relate to the agency of the Excretory apparatus in maintaining the purity of the Blood, have been extended. This chapter, however, is less comprehensive than formerly; several of the subjects which it previously included, having been transferred to portions of the work in which they seemed to find more appropriate places; the Salivary and Pancreatic secretions being now treated-of in the Chapter on Digestion, and those of the Testes and Mammary Glands in that on Generation. Of the three subjects included in Chapter XIII., "On the Evolution of Heat, Light, and Electricity," the first alone had been systematically considered in the previous editions, and this has been considerably extended in the present; under the second head will be found some very curious observations on the evolution of Light in the living Human subject; and under the third is given a summary of the results of the admirable researches of M. Du-bois Reymond, which have been recently brought before the scientific public in this country by Dr. Bence Jones.

It is in the Chapter (XIV.) devoted to the Functions of the Nervous System, which constitutes one-fifth of the entire volume, that the greatest additions and alterations will be found. This subject, in its Psychological as well as in its Physiological relations, has occupied more of the Author's attention than any other department of Physiology; and he now offers the more matured fruits of his inquiries and reflections, with some confidence that, even if his views should hereafter require modification as to details, they will be found to be fundamentally correct, and to furnish materials of some value in Psychological inquiry, as well as in the study of Mental Pathology,—a subject which is now receiving for the first time

(in this country, at least) the attention which its vast importance demands. The peculiar states which are known under the designations of Somnambulism, Hypnotism, Mesmerism, Electro-Biology, &c., are all considered in their relations to Sleep on the one hand, and to the ordinary condition of Mental Activity on the other; and the Author ventures to believe that he has not only succeeded in throwing considerable light upon the nature of these aberrant forms of psychical action, but that he has been enabled to deduce from their phenomena some inferences of great importance in Psychological science. He would particularly refer to all that portion of Section 5 ("On the Cerebrum and its Functions"), which relates to the *Automatic* operations of the Mind, and to the relation of the *Will* to these, as opening-up what he believes to be an entirely new line of inquiry.

It is with great satisfaction that he can refer to his friends, Dr. Holland and Dr. Laycock, as participating (with regard to all essential points at least) in his own views on all these subjects; and though all which he has here written upon them is the expression of the results of his own observation and reflection, yet he gladly takes this opportunity of acknowledging the great benefit which he has derived from the writings and conversation of these philosophical and independent thinkers. It would be ungrateful if he were not also to record his obligations to his friends, Mr. John Mill and Mr. Daniel Morell, who have allowed him to bring his Psychological views under their notice, from time to time, and to subject them to the test of their own far more extensive and profound acquaintance with that department of his inquiry.

In Chapter xv., "On Sensation, and the Organs of the Senses," comparatively little change has been made; several additions have been introduced, however, and some corrections made. The next Chapter (xvi.), "On Muscular Movements," has been entirely remodelled, the portion which relates to the vital endowments of Muscular Fibre having been removed to Chapter v., Section 6, and its place supplied by new matter which contains many original views, especially under Section 4, which treats of "the influence of Expectant Attention on Muscular Movements." Comparatively little alteration has been found necessary in Chapter xvii., "On the Voice and Speech," or in Chapter xviii., "On the Influence of the Nervous System on the Organic Functions;" an important addition has been made to the latter, however, with reference to the influence of the state of 'expectant attention' on the operations of Nutrition, Secretion, &c.

The additions and alterations which have been made in Chapter xix., "On Generation," will be found to be both numerous and important, especially under the Section on the "Development of the Embryo;" which

has been almost entirely re-written, so as to bring the view of this process more into accordance with the existing state of our knowledge of it. The Author has not felt it expedient, however, (for the reasons mentioned in § 922) to enter into minute details upon this subject.

In Chapter xx., "On the Different Branches of the Human Family, and their Mutual Relations," all that directly relates to its subject has been considerably extended, and many novelties have been introduced; whilst those arguments for the Specific Unity of the Human Races, which are derived from the analogy of the lower animals, have been simply referred-to,—having been fully dwelt-on by the Author elsewhere.

The closing Chaper, "On Death," has been almost entirely written for this Edition; the subject having been only touched-on incidentally in the preceding.

The Author trusts that it will be apparent, from the foregoing summary, that he has spared no pains to render the present Edition worthy of the favourable reception which has been accorded to its predecessors. The principle he has adopted throughout, has been that of making the Treatise express his present convictions and opinions, as completely as if it were now for the first time put forth; the old materials having been incorporated with the new, rather than the new with the old; and having only been employed, where they could be readily made subservient to this purpose. In making his selection from the vast mass of results which have been recently accumulated by the diligent labours of Physiologists of various countries, the Author has been guided by the principle which he expressed in the Preface to his previous Edition;—that, namely, of not rashly introducing changes inconsistent with usually-received views;—nor, on the other hand, showing an unwillingness to reject the statements of those who have taken adequate pains to arrive at accurate conclusions. "He trusts that he may be found"— *now* as *then* —"to have exercised a sound discretion, both as to what he has admitted, and what he has rejected; and that his work will appear to exhibit, on the whole, a faithful reflection of the present aspect of Physiological Science. He cannot venture to expect, however, that he has succeeded in every instance, so that each of his readers will be in constant agreement with him; since it is impossible that they should all survey the subject from the same point of view."

In conformity with a desire frequently expressed, both by critics and readers, a large number of references have been introduced; and to this addition, no small portion of the augmented bulk of the volume is due. Here, as in his companion-work, the Author has felt himself compelled, by want of space, "to limit his references, for the most part,

to those *new* facts and doctrines, which cannot yet be said to have become part of the common stock of Physiological Science." The special Index of "Authors referred-to," will be found, he hopes, of service to those who wish to know the views of the original writers quoted, upon any particular topic. To the knowledge of many of these, he has been led by the excellent "Hand-book of Physiology" of Messrs. Kirkes and Paget, to which he gladly expresses his obligations in this particular. He has himself consulted the originals, however, in all cases in which he could gain access to them.

In conclusion, the Author would repeat the remark with which he brought to a close the Preface to the first Edition (1842);—"that in a work involving many details, it is not to be expected that no error should have crept in; but that he has endeavoured to secure correctness, by relying only upon such authorities as appeared to him competent, and by comparing their statements with such general principles as he considers well established. For the truth of those principles, he holds himself responsible; for the correctness of the details, he must appeal to those from whom they are derived, and to whom he has generally referred. He hopes that he will not be found unwilling to modify either, when they have been proved to be erroneous; nor indisposed to profit by criticism, when administered in a friendly spirit."

UNIVERSITY HALL, November, 1852.

# TABLE OF CONTENTS.

## INTRODUCTION.



## CHAPTER I.



## CHAPTER II.



## CHAPTER III.



## CHAPTER IV.

## CHAPTER V.



## CHAPTER VI.



## CHAPTER VII.



## CHAPTER VIII.



## CHAPTER IX.

## CHAPTER X.



## CHAPTER XI.



## CHAPTER XII.



## CHAPTER XIII.



## CHAPTER XIV.



## CHAPTER XV.

## CHAPTER XVI.



## CHAPTER XVII.



## CHAPTER XVIII.



## CHAPTER XIX.



## CHAPTER XX.



## CHAPTER XXI.

# TABLE OF ILLUSTRATIONS.

## PLATE I.

FIG.

1. Spermatozoa of Man; A, viewed on the surface; B, viewed edgeways (§ 958).
2. Vesicles of evolution from the seminal fluid of the Dog; A, B, C, single vesicles of different sizes; D, single vesicle within its parent-cell; E, parent-cell enclosing seven vesicles of evolution (§ 959).
3. Development of Spermatozoa within the vesicles of evolution; A, B, vesicles containing spermatozoa in process of formation; C, D, spermatozoa escaping from the vesicles (§ 959).

[The three preceding figures are after Wagner and Leuckardt ("Cyclop. of Anatomy and Physiology," Art. 'Semen').]

4. Thin slice of the ovarium of a Sow three weeks old, showing the Graafian vesicles or ovisacs imbedded in a fibro-cellular stroma. The ovisacs are filled with cells, in the midst of which one large one may be specially distinguished; this, which is the germinal vesicle, is surrounded by minute granules, which constitute the first indication of the yolk (§ 963).
5. Ovum of a Rabbit, showing the vitelline mass almost entirely converted into distinct cells, of which those at the surface are pressed against each other and against the zona pellucida, so as to assume a hexagonal form. The dark portion consists of a mass of vitelline spheres, which has not undergone this conversion (§ 996).
6. Ovum of the Rabbit, seven days after impregnation, viewed on a black ground. The outer membrane is the chorion, on which are seen incipient villosities. Within this is the *blastodermic vesicle*, at the summit of which is the projection formed by the *area germinativa;* and from this the mucous layer of the germinal membrane is seen to extend over about one-third of the surface of the contained yolk (§ 996).
7. Portion of the germinal membrane, taken from the *area germinativa*, to show the two layers of which it is composed; the *serous*, or animal layer, is turned back, so as to show the *mucous* or vegetative layer *in situ*. In the latter is seen the *primitive trace* (§ 996).
8. Portion of the *serous* layer of the germinal membrane, highly magnified; showing that it is made-up of nucleated cells, united by intercellular substance, and filled with minute molecules (§ 996).
9. Portion of the *mucous* layer of the germinal membrane, highly magnified; showing that it is made-up of cells, whose borders are more distinct and more closely applied to each other than those of the serous layer, and whose contents are more transparent (§ 996).

[The six preceding figures are after Bischoff ("Entwickelungsgeschichte der Säugethiere," &c. (1842), — "des Kanincheneies" (1842), — "des Hunde-eies" (1845).]

FIG.

10. Gravid uterus of a Woman who had committed suicide in the seventh week of pregnancy, laid open; *a*, os uteri internum; *b*, cavity of the cervix; *c*, *c*, *c*, *c*, the four flaps of the body of the uterus turned back; *d*, *d*, *d*, inner surface of uterine decidua; *e*, *e*, decidua reflexa; *f*, *f*, external villous surface of the chorion; *g*, internal surface of the chorion; *h*, amnion; *i*, umbilical vesicle; *k*, umbilical cord; *l*, embryo; *m*, space between chorion and amnion (§§ 919–921, and 938, 939). [After Wagner ("Icones Physiologicæ").]

## PLATE II.

11. Uterine Ovum of Rabbit, showing the Area Pellucida, with the primitive trace (§ 937).
12. More advanced ovum, showing the incipient formation of the Vertebral column, and the dilatation of the primitive groove at its anterior extremity (§ 937).
13. More advanced embryo, seen on its ventral side, and showing the first development of the Circulating apparatus. Around the Vascular Area is shown the terminal sinus, *a*, *a*, *a*. The blood returns from this by two superior branches, *b*, *b*, and two inferior *c*, *c*, of the omphalo-meseraic veins, to the heart, *d*; which is, at this period, a tube curved on itself, and presenting the first indication of a division into cavities. The two aortic trunks appear, in the abdominal region, as the inferior vertebral arteries, *e*, *e*; from which are given off the omphalo-meseraic arteries, *f*, *f*, which form a network that distributes the blood over the vascular area. In the cephalic region are seen the anterior cerebral vesicles, with the two ocular vesicles *g*, (§§ 938, 940).

[The three preceding figures are from the works of Bischoff previously cited.]

## PLATE III.

(To face page 12).

Comparative View of the Skeleton of Man, and that of the Orang Outan. [After Owen ("Zoological Transactions," vol. i.).]

## LIST OF WOOD-ENGRAVINGS.

# INTRODUCTION.

The object of the science of Physiology is to bring together, in a systematic form, the phenomena which normally present themselves during the existence of living beings; and to classify and compare these in such a manner, as to deduce from them those general *Laws* or *Principles* which express the conditions of their occurrence, and to determine the *Causes* to which they are attributable.

The term "Law" having been frequently applied to physical and physiological phenomena, in a manner very different from that which sound philosophy sanctions, it is desirable to explain the acceptation (believed by the author to be the *only* legitimate one), in which it is here employed. Viewed in their scientific aspect, the so-called *Laws of Nature* are nothing else than general expressions of the conditions under which certain assemblages of phenomena occur, so far as those conditions are known to us. Thus the law of Gravitation in General Physics (the most comprehensive of any with which we are acquainted), is nothing else than a simple expression of the fact, that, under all circumstances, two masses of matter will attract each other, with forces directly proportional to their respective bulks, and inversely as the square of their distances. So, again, the law of Cell-growth, which seems to hold nearly the same rank in Physiology with that of Gravitation in Physics, embodies these two general facts, (1), that all organized beings originate in cells, and (2), that the various functions of life are carried on, even in the adult condition, by the continued growth and development of cells.

It is a very common fallacy, however, to assume that we have sufficiently *accounted for* a phenomenon, when we have referred it to a "general law." Thus if a man be asked why a stone falls to the earth, he commonly considers that he gives a satisfactory explanation when he replies, "Because of the Law of gravitation." But it must be remembered that this "law of gravitation" *is* a law, that is, a generalized expression of facts, only because *all* stones fall to the earth, and *all other* masses of

matter (so far as we know) towards each other; therefore, to say that a stone falls to the earth *because* of the law of gravitation, is merely to say that two bodies are attracted together *because* all others are,—which is obviously nothing else, than an extension of the statement from the particular to the general fact. It cannot, indeed, be kept too constantly in view, "that in science, those who speak of explaining any phenomenon mean (or should mean) pointing out not some more familiar, but merely some more general phenomenon, of which it is a partial exemplification;" —the explanation being accounted most complete, when the conditions of such general phenomenon can be expressed in the precise form of a "law," with which those of the particular case can be shown to accord, and from which, therefore, its occurrence may be predicted deductively. The whole problem of the scientific investigation of Nature may, indeed, be thus stated:—"What are the fewest assumptions, which, being granted, the order of nature as it exists would be the result? What are the fewest general propositions, from which all the uniformities existing in nature could be deduced?" *

In its scientific acceptation, therefore, a Law of Nature must be admitted to possess no *coercive* power whatever; and to speak of phenomena as being *governed* by laws, is altogether incorrect. The only sense in which this form of expression can be admitted to have any true meaning, is when the *law* is the expression of a *will*, which is potent to produce, to direct, or to restrain the actions to which it relates. Thus the laws of a State are expressions of the Will of the governing power, intended to regulate the conduct of the community over which it rules; and they become entirely inoperative, from the moment when that power ceases to be effectual to carry out the purposes which it has thus announced. So then, if we recognize in the Universe the existence of a sustaining and controlling Power, we may regard the Laws of Nature which Man has discovered, as expressions of the plan (so far as he has succeeded in unveiling it) according to which that Power acts; and we may then legitimately speak of the phenomena of Nature as *governed by*, or rather *taking place according to*, Laws,—it being always borne in mind, however, that these laws are mere *human* expressions of the plan on which the Divine Power *seems to* operate, and may be not only very imperfect, but also very incorrect. The moment, then, that we attribute to Laws of Nature a *coercive* efficacy, we pass from the domain of Natural Science into that of Theology; and *imply*, if we do not formally recognize, the existence of a Power, of whose *modus operandi* these laws are the presumed exponents.†

* See "Elements of Logic," by Mr. J. S. Mill, 3rd ed. vol. i. p. 486.

† The neglect of this distinction has led to many fallacies; not the least of which is, that

The sense in which the term *Cause*, also, is to be employed, should be clearly understood at the outset of any scientific inquiry that involves its use; more especially, since there is a considerable discrepancy between the popular acceptation of the word, and the meaning which is now generally assigned to it by logicians: and it is peculiarly necessary for the correctness of Medical reasoning, that its import should be definitely settled. When the "cause" of any event is spoken of, in common parlance, we certainly attach to the term the idea of *power*, at the same time that we include the notion of the *conditions* under which that power operates; and this practical view of the case will be found (as the Author believes) to be the correct one. On the other hand, the logician draws a distinction between the "efficient" and the "physical" cause of any phenomenon, dismisses the former as a matter with which scientific inquiry is not legitimately concerned, and applies himself to the consideration of the latter alone, which he defines to be "the antecedent, or the concurrence of antecedents, on which it is invariably and unconditionally consequent." (Mill, op. cit.) But when this assemblage of antecedents is analyzed, it is uniformly found that they may be resolved into two categories, which may be distinguished as the *dynamical* and the *material*: the former supplying the *force* or *power* to which the change must be attributed; whilst the latter afford the *conditions* under which that power is exerted. Thus in a Steam-Engine, we see the dynamical agency of Heat made to produce mechanical power, by the mode in which it is applied—first, to impart a mutual repulsion to the particles of water,—and then, by means of that mutual repulsion, to give motion to the various solid parts of which the machine is composed. And thus, if asked what is the cause of the movement of the Steam-Engine, we distinguish in our reply between the *dynamical* condition supplied by the Heat, and the *material* condition (or assemblage of conditions) afforded by the collocation of the boiler, cylinder, piston, valves, &c. So, again, if we are asked what is the cause of the movement of a spinning-jenny, we refer it to its connection by bands or wheels with some shaft, which itself derives its power to move from a steam-engine or water-wheel; these material collocations here again serving to supply the conditions, under which that Force becomes operative. In like manner, if we inquire into the causes of the germination of a seed,—which has been brought to the surface of the earth, after remaining dormant, through having been buried deep beneath the soil, for (it may be) thousands of years,—we are told that the phenomenon depends upon warmth, moisture, and oxygen: but out of these we single warmth as the *dynamical* condition; whilst the oxygen and the

the discovery of a scientific law affords a sufficient account of the occurrence of natural phenomena; and that the notion of the personal agency of the Deity in their production is, therefore, an unwarrantable assumption.

water, with the organized structure of the seed itself, and the organic compounds which are stored up in its substance, constitute the *material.*

A strictly scientific inquiry, then, *must* recognize Dynamical agency, as well as Material condition; and it will be found that this is peculiarly requisite in the Science of Life, which has been pursued by some as if it were a sufficient account of every phenomenon not otherwise explicable, to refer it to a "vital principle;" whilst others have endeavoured to reduce all Physiological causation to a set of material conditions, maintaining that Life entirely depends on "organization," and that the hypothesis of a vital principle is consequently unnecessary and unphilosophical. Others, again, who have recognized the operation of Physical and Chemical agencies in the living body, have maintained that all Vital action is but a peculiar manifestation of heat, mechanical power, chemical affinity, and the like; and have thus attempted to break down the barrier between the Organized and the Inorganic creation. The Author has elsewhere* endeavoured to show, that we have evidence of the operation of a *power* in the living body, whose manifestations are so different from those of any of the Physical Forces, that we cannot reasonably refrain from giving it a distinctive designation; and that this "Vital Power" may exert itself in a great variety of modes, and may consequently produce a great variety of phenomena, according to the material conditions of its operation,—just as (though the comparison be somewhat clumsy) the mechanical power which turns the engine-shaft in an extensive factory, is rendered efficient for an immense variety of purposes, according to the construction and arrangement of the several machines through which it is distributed. And further, he has attempted to prove, that the source of this Vital Power is to be found, not in the organization of the being itself, but in the forces which operate upon it *ab externo;* and that it has the same close and intimate relation with the Heat, Electricity, Chemical Affinity, and other agencies of the Inorganic world, which they have been proved to have with each other:—so that, just as Heat acting upon water generates Mechanical force, or when applied to a certain combination of metals excites Electricity, so, when brought to bear upon a torpid animal or upon a seed (in which the material conditions of this activity are present), it manifests itself as Vital Force, and is the immediate dynamical condition of the phenomena of growth, development, &c.

But further, the term *Cause* has a Theological as well as a Scientific sense; and, like the two usages of the term Law, these two acceptations are perfectly harmonious, although in themselves different. When in scientific inquiry we have traced a multitude of complex phenomena up to

* See his Memoir "On the Mutual Relations of the Vital and Physical Forces," in the Philosophical Transactions for 1850.

a single force, and have shown that their variety is due only to the diversity of the conditions under which that force is operating, we still have to ascertain the source of this force; and it is no sufficient account of it to show that it is but a metamorphosed form of some other force. We may even be led by Science to look upon all the phenomena of the Universe as the results of the operation of a single dynamical agent, varied in the modes of its manifestation according to the nature of the mechanism (so to speak) which it puts in action. The existence of this force, *causa causarum*, still remains unaccounted for; but at this point Physical Science ends, and the question becomes one of an entirely different order. The inquiring mind cannot stop here; and if it seek a solution in its own experience, it is led by the consciousness that by *its own volition* it can give rise to a *force* which is capable of operating upon the material world, to look to an Intelligent Will as the ultimate spring of all those changes for which it can find no other source, and to regard the Forces of the Universe in general as so many modes of operation of the one Omnipotent and Omnipresent Mind.—Viewed under this aspect, therefore, all the phenomena of Nature which have not their origin in the mental power of subordinate beings, must be considered as the immediate exponents of the Will of the Creator; and thus again we are led to regard their so-called "Laws," as but Man's expression of the conditions under which the Divine Power appears continually operative in producing them.

In a purely Scientific Treatise, however, it is in the *scientific* sense alone that the terms "Cause" and "Law" are to be understood; and wherever they occur in the following work, therefore, the Author would imply by the former the exercise of a *force* or *power*, Physical or Vital, operating under certain definite *material* conditions; whilst by the latter he would designate every such general exponents of those conditions under which a force operates, as may enable the results to be determined before-hand. Thus the Law of Gravitation defines in general terms that constant relation between the bulk and the distance of masses of matter, on the one hand, and the amount of force which is developed by their mutual attraction, on the other, which enables us, by an acquaintance with the particulars of the former, to predicate those of the latter. And the Law of Definite Proportions expresses in general terms that relation between the "combining equivalents" of different substances, which enables us, when we apply it to particulars, to determine precisely how much of a compound substance will be decomposed by the force of Chemical attraction, which a given amount of another substance may exert upon one of its components, and what will be the nature and constitution of the product.

In order to determine the most general laws of Physiological Science, a very extensive comparison is requisite. Principles, which might seem

of paramount importance in regard to one group of living beings, are often found, on a more extended review, to be quite subordinate. For example, the predominance of the Nervous System in the higher classes of Animals, and its evidently-close connection with many of the functions of life, has led several Physiologists to the opinion, that its influence is *essential* to the performance of the functions of Nutrition, Secretion, &c.; but, on turning our attention to the Vegetable kingdom, in which nothing analogous to a nervous system can be proved to exist, we find these functions going on with even greater activity than in animals. It is clear, therefore, they *may* be performed without it; and, on a closer examination of the phenomena presented by Animals, it is seen that these may be explained better, on the principle that the nervous system has a powerful influence on such actions, than on the idea that it affords a condition essential to them. Recent inquiries have shown, that the agents *immediately* concerned in these operations are of the same nature in both kingdoms; the separation of the nutrient materials from the circulating fluid, or the elimination of substances which are to be withdrawn from it, being performed in the Animal, as in the Plant, by *cells*, in the manner to be explained hereafter. —This is only one out of many instances, which it would be easy to adduce, in proof of the necessity of bringing together *all* the phenomena of the same kind, in whatever class of living beings they may be presented, before we attempt to erect any general principles in Physiology.

The object of the present treatise, however, is not to follow out such an investigation, which has been pursued, as fully as his limits would allow, in the Author's "Principles of Physiology, General and Comparative:" but to show the detailed application of the principles of which Physiological science may now be said to consist, to the phenomena exhibited by the Human organism, during the continuance of *health* or *normal life.* These phenomena, when they occur in a disturbed or irregular manner, constitute *disease* or *abnormal life;* and become the subjects of the science of Pathology. It is impossible to draw a precise line of demarcation between the states of health and disease; since many variations occur, which do not pass the limits of what must be called in some individuals the normal state, but which must be regarded as decidedly abnormal conditions in others. The sciences of Physiology and Pathology, therefore, are very closely related; and neither can be pursued with the highest prospect of success, except in connection with the other. It is now coming to be generally felt, that our fundamental ideas of healthy vital action must rest on the knowledge of the structure, composition, and properties of the minutest portions of the fabric; and in like manner, our fundamental notions of the changes in which disease essentially consists, are coming to rest more and more upon the detection of the perversions which the actions of these parts undergo,

and of the minute alterations of structure and composition which they involve. It is, in fact, in the detection of those *first departures* from the normal actions which frequently constitute the essence of a disease, and in the determination of the causes to whose operation they are referable, that Medical Science is at present making the greatest progress; and it would not be difficult to show, that this progress is intimately connected with the advance of Physiology. To say that it is impossible to interpret the phenomena of disease with any probability of correctness, impossible to apply remedies with a reasonable expectation of success,—impossible, therefore, to practise the healing art as it ought to be practised,—unless we are acquainted with the normal or healthy action of the system, might seem a truism; and yet, however self-evident the truth of the assertion, it is very far from having the weight which it ought to possess. The phenomena of Disease have been isolated from those of Health, as if they belonged to quite a distinct category, and were dependent upon a set of causes altogether dissimilar. It has been too much lost sight of, that every diseased action is but a perversion, by *excess*, by *diminution*, or by *depravation*, of some natural function; and that only through an acquaintance with the latter can the former be understood (otherwise than in a merely empirical fashion), either as to its cause, its nature, or its tendencies. It has been assumed by some Pathologists, that Physiology ought to furnish a set of direct rules for the treatment of disease; and, as it cannot rightly profess to furnish these, it has been set down by others as having no practical value whatever. Whereas the real Medical Philosopher rather looks to Physiology as affording guidance in the pursuit of those rules, by furnishing a clue to his interpretation of symptoms, by pointing out the direction in which he may look for remedies, and by letting in, here and there, a beam of light that shall guide him through the intricacies of his search. In fact, it is with this constant but unobtrusive assistance from Physiology, that the Pathologist advances in his career of research; and hence it is just where our Physiological knowledge is most precise, and its generalizations most comprehensive, that our Pathological information is most advanced and most fruitful in practical results.

It may be taken, indeed, as a general fact, that those Arts, or collections of rules for a given purpose, are the most perfect in their application, which are built upon the most secure foundation in Science. "It is the office of science," says Bacon, "to shorten the long turnings and windings of experience;" and in proportion as Medical Science becomes so perfect, that it can not only say what *is*, or what *happens*, in the human body, in the state of health or disease, but also what *will* happen when the conditions are altered, in that proportion, it is evident, will it be

possible to frame rules or directions for conduct,—expressing "*do* this," "*avoid* that,"—from the practice of which a certain result may be predicted. And if, at the present time, there should be more doubt than perhaps ever previously existed in the minds of the Profession at large, with regard to the efficacy of many plans of medical treatment, in spite of the strong testimony as to their value which has been traditionally handed down, it is because, for the most part, the confidence which has been felt in them has rested upon too narrow a foundation of imperfectly-scrutinized experience, and a definite scientific *rationale* has been either found wanting altogether, or, if it had a supposed existence, has been shown to have been fallacious. But, on the other hand, whilst many time-honoured traditions have thus been overthrown, new doctrines have been advanced with all that assurance of value which is afforded by the clear and positive direction which Science affords; and to these the intelligent practitioner will attach himself as his securest guides, confident that, even if the practice they inculcate may not lead him to the success he desires, they will not antagonize the efforts which Nature may be making to effect a cure in her own way.

Whilst it will be the special object of the following Treatise, therefore, to show in what that *normal activity* of the human body, which we call *Health*, consists, and to explain the conditions upon which its continuance is dependent, the reader's attention will be directed from time to time to the practical rules which arise out of the application of Physiological Science to the Art of Hygiène; and in like manner, when speaking of the most frequent of those perversions of normal activity, in which *Disease* consists, some of the most important of those principles of treatment will be laid down, which constitute the application of Pathological Science to the Art of Therapeutics.

In proportion as the treatment of disease shall be thus withdrawn from the domain of empiricism, and be founded on scientific principles, in that proportion will the Medical Profession acquire that dignified confidence in itself, which shall keep it steady to its high and noble aims; and will attain that general estimation, which will be freely accorded to its enlightened and disinterested pursuit of them.

PLATE I

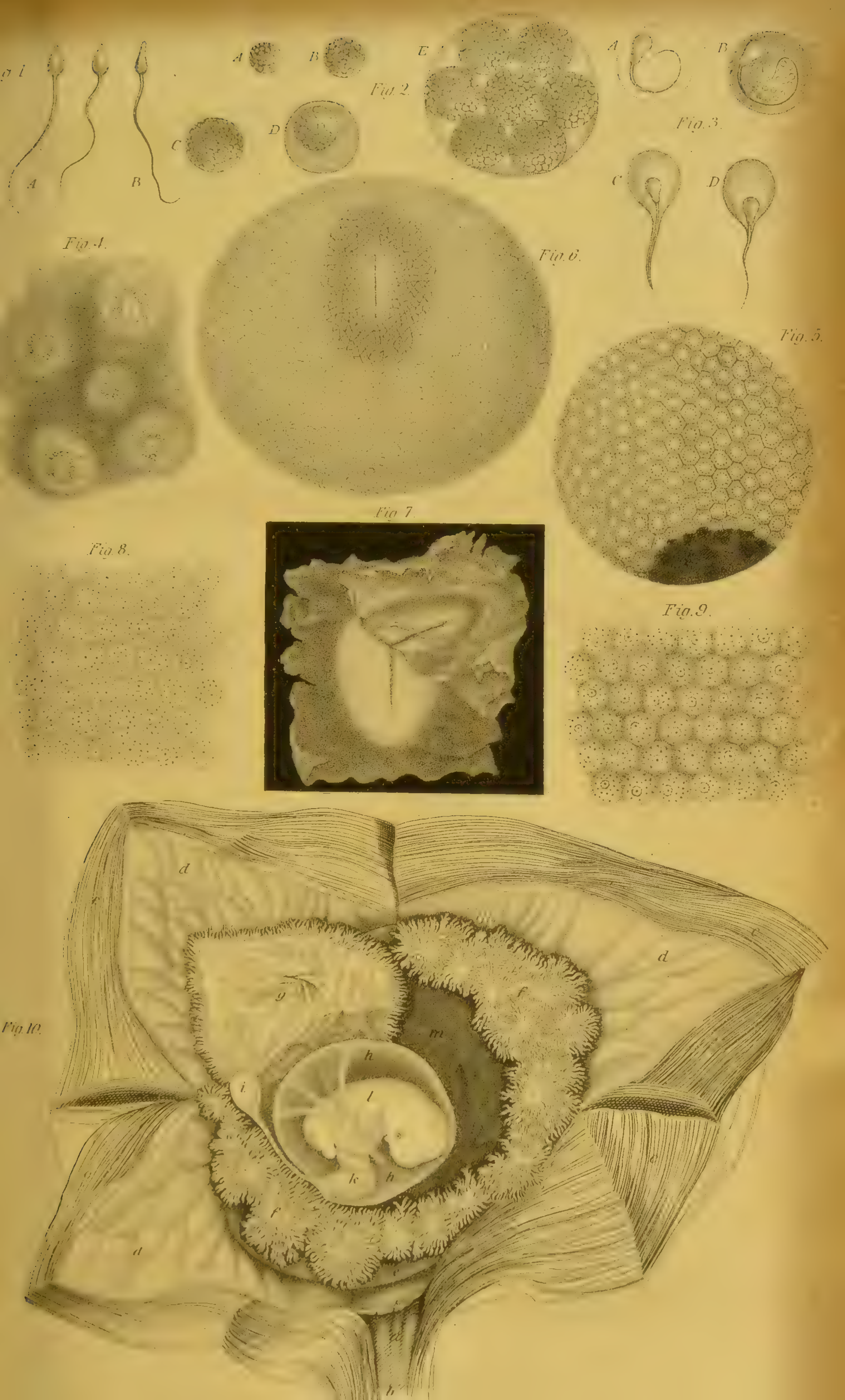

Fig. 1
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Fig. 2
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Fig. 3
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Fig. 11

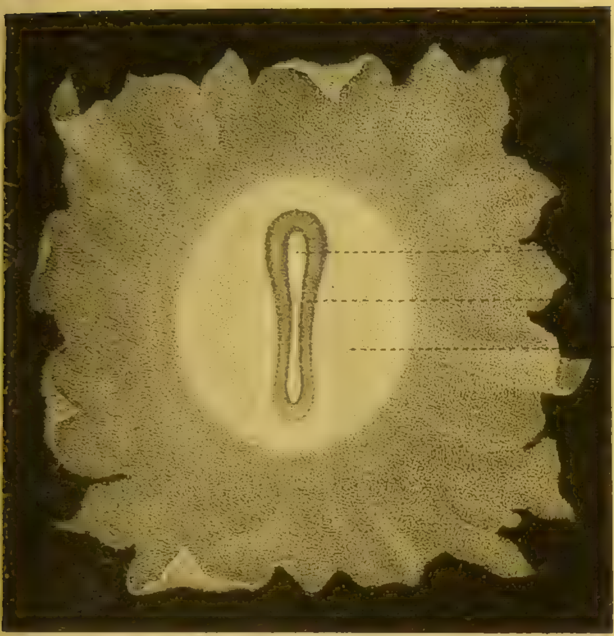



Fig. 12.

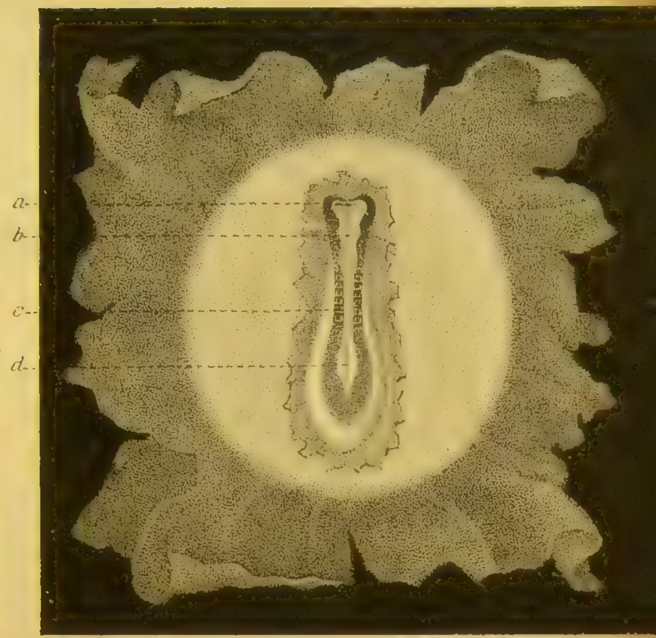
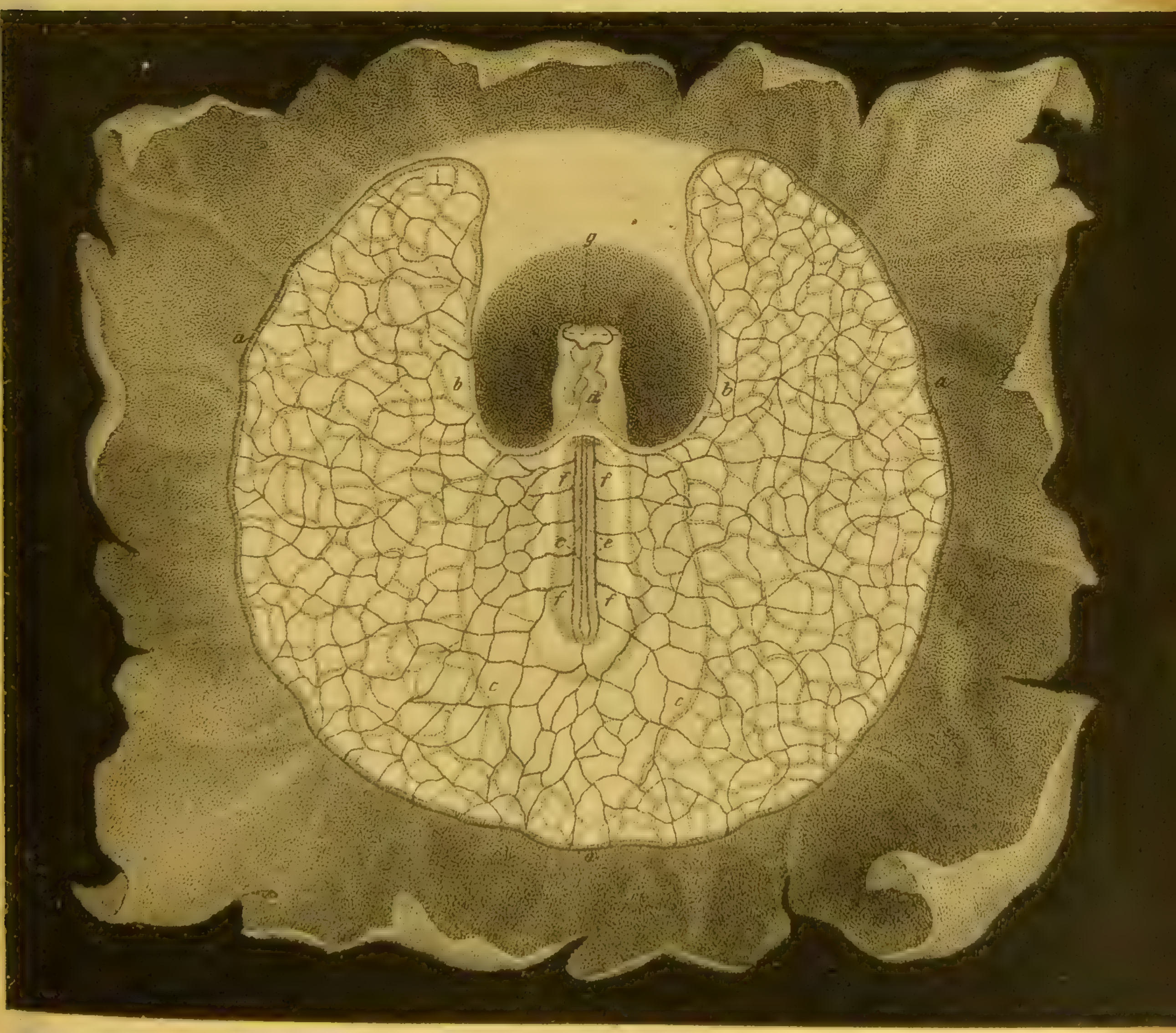



Fig. 13.




H. Adlard sc.

# CHAPTER I.

## OF THE DISTINCTIVE CHARACTERISTICS OF MAN.

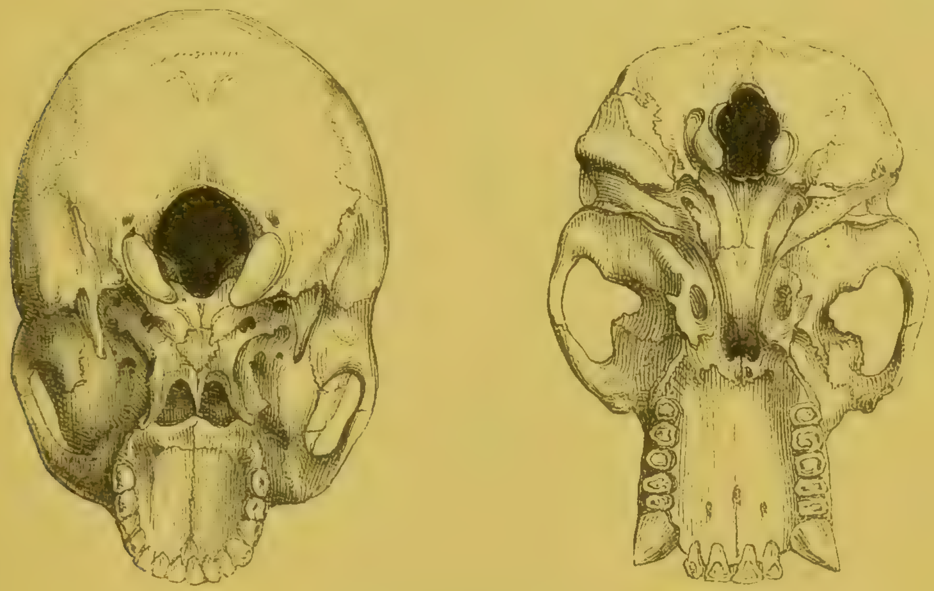
1. By Cuvier and nearly all modern Zoologists, the various races of Mankind are included under one genus, *Homo;* and this genus takes rank, in the classification of Mammalia, as a distinct order, Bimana, of which it is the sole representative. Of all the characters which distinguish Man from the inferior Mammalia, the possession of *two hands* is doubtless the most easily recognized, and at the same time the most intimately related to the general organization of the body; and there is none, therefore, which could be more appropriately selected as the basis of a distinctive designation of this order. At first sight it might be considered that the possession of only *two* hands, whilst Apes and Monkeys and their allies are designated as possessing *four*, is a character of inferiority; but such is not really the case; for none of these four hands are adapted to the variety of actions of which those of man are capable, and they are all in some degree required for support; so that whilst in the higher forms of the Quadrumanous order, the extremities present a certain approximation in structure to those of Man, in the lower they gradually assimilate to the ordinary quadrupedal type. "That," says Cuvier, "which constitutes the *hand*, properly so called, is the faculty of opposing the thumb to the other fingers, so as to seize upon the most minute objects; a faculty which is carried to its highest degree of perfection in Man, in whom the whole anterior extremity is free, and can be employed in prehension." The peculiar prehensile power possessed by Man is chiefly dependent upon the size and power of the thumb; which is more developed in Man, than it is in the highest apes. The thumb of the human hand can be brought into exact opposition to the extremities of all the fingers, whether singly or in combination; whilst in those Quadrumana which most nearly approach Man, the thumb is so short, and the fingers so much elongated, that their tips can scarcely be brought into opposition; and the thumb and fingers are so weak, that they can never be opposed to each other with any degree of force. Hence, although admirably adapted for clinging round bodies of a certain size, such as the small branches of trees, &c., the extremities of the Quadrumana can neither seize very minute objects with such precision, nor support large ones with such firmness, as are essential to the dexterous performance of a variety of operations, for which the hand of Man is admirably adapted. There is much truth, then, in Sir C. Bell's remark, that "we ought to define the hand as belonging exclusively to man." There is in him, what we observe in none of the Mammalia which approach him in other respects, a complete distinction in the functional character of the anterior and posterior

extremities; the former being adapted for prehension alone, and the latter for support and progression alone; and thus each function is performed in a much higher degree of perfection, than it can be when two such opposite purposes have to be united. For not only is the hand of Man a much more perfect prehensile instrument than that of the Orang or Chimpanzee, but his foot is a much more perfect organ of support and progression than theirs, being adapted to maintain his body in an erect position, alike during rest and whilst in motion,—an attitude which even the most anthropoid apes can only sustain for a short time, and with an obvious effort. The arm of the higher apes has as wide a range of motion as that of Man, so far as its articulation is concerned; but it is only when the animal is in the erect attitude, that the limb can have free play. Thus the structure of the whole frame must be conformable to that of the hand, in the way that we find it to be in Man, in order that this organ may be advantageously applied to the purposes which it is adapted to perform. But it cannot be said with truth (as some have maintained) that Man owes his superiority to his hand alone; for without the *mind* by which it is directed, and the *senses* by which its operations are guided, it would be a comparatively valueless instrument. Man's elevated position is due to the superiority of his mind and of its material instruments conjointly; for if destitute of either, the human race must be speedily extinguished altogether, or reduced to a very subordinate grade of existence.

2. The next series of characters to be considered, are those by which Man is adapted to the erect attitude.—On examining his *cranium*, we remark that the occipital condyles are so placed, that a perpendicular dropped from the centre of gravity of the head would nearly fall between them, so as to be within the base on which it rests upon the spinal column. The foramen magnum is not placed in the centre of the base of the skull, but just behind it; so that the greater specific gravity of the posterior part of the head, which is entirely filled with solid matter, is compensated by the greater length of the anterior part, which contains many cavities. There is, indeed, a little over-compensation, which gives a slight preponderance to the front of the head, so that it drops forwards and downwards, when all the muscles are relaxed; but the muscles which are attached to the back of the head are far larger and more numerous than those in front of the condyles, so that they are evidently intended to counteract this disposition; and we find, accordingly, that we can keep up the head for the whole day, with so slight and involuntary an effort, that no fatigue is produced by it. Moreover, the plane of the foramen magnum, and the surfaces of the condyles, have a nearly horizontal direction when the head is upright; and thus the weight of the skull is laid vertically upon the top of the vertebral column. If these arrangements be compared with those which prevail in other Mammalia, it will be found that the foramen and condyles are placed in the latter much nearer the back of the head, and that their plane is more oblique. Thus, whilst the foramen magnum is situated, in Man, just behind the centre of the base of the skull, it is found, in the Chimpanzee and Orang Outan, to occupy the middle of the posterior third (Fig. 1); and, as we descend through the scale of Mammalia, we observe that it gradually approaches the *back* of the skull, and at last comes nearly into the line of its longest

diameter, as we see in the Horse. Again, in all Mammalia except Man, the plane of the condyles is oblique, so that, even if the head were equally balanced upon them, the force of gravity would tend to carry it forwards

FIG. 1.



View of the base of the skull of *Man*, compared with that of the *Orang Outan.*

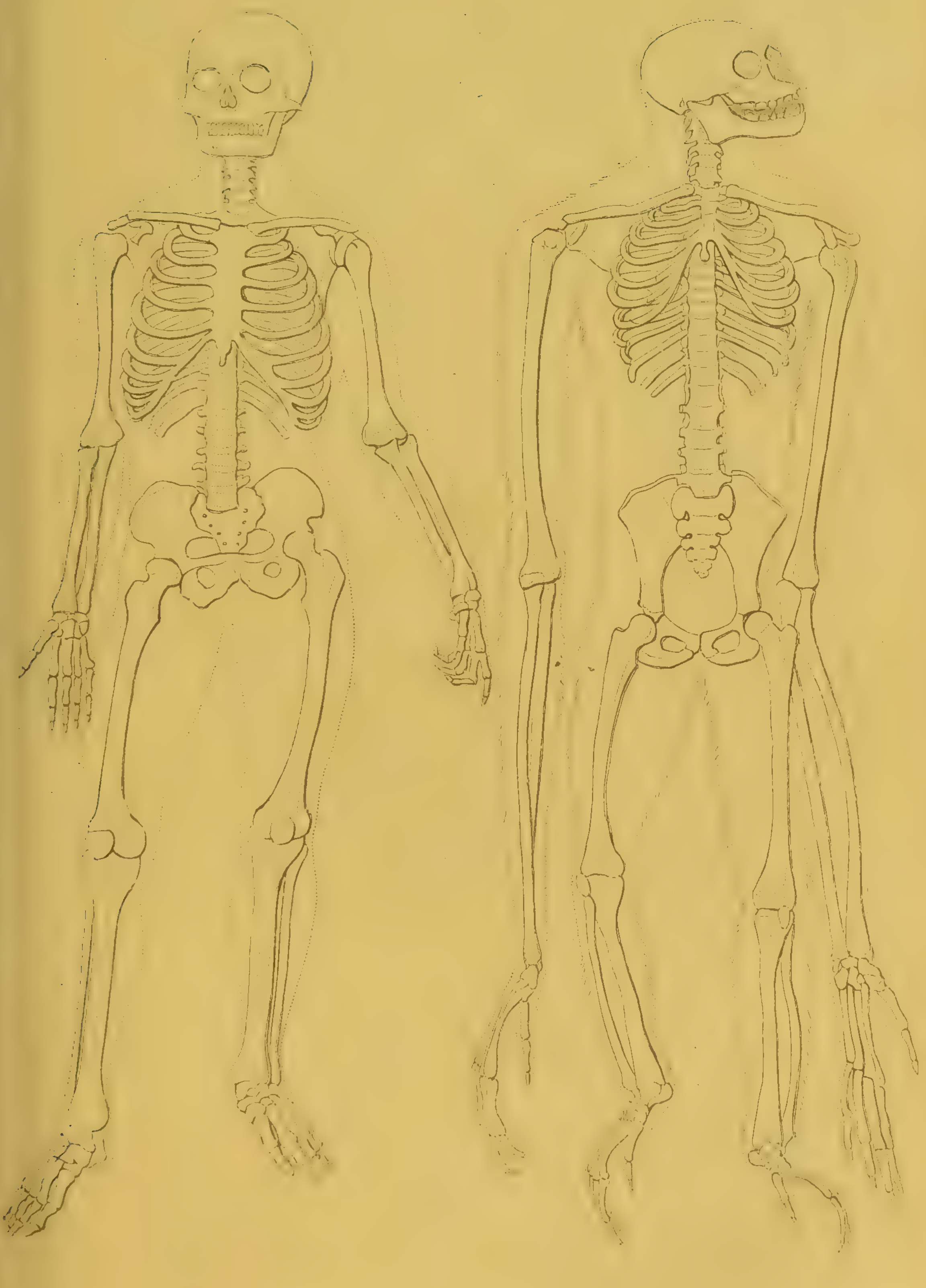
and downwards: in Man, the angle which they make with the horizon is very small; in the Orang Outan, it is as much as 37°; and in the Horse, their plane is vertical, making the angle 90°. If, therefore, the natural posture of Man were horizontal, the plane of his condyles would be brought, like that of the Horse, into the vertical position; and the head, instead of being nearly balanced on the summit of the vertebral column, would hang at the end of the neck, so that its whole weight would have to be supported by some external and constantly-acting power. But for this, there is neither in the skeleton, the ligamentous apparatus, nor the muscular system of Man, any adequate provision; so that in any other than the vertical position, his head, which is relatively heavier than that of most Mammalia, would be supported with more difficulty and effort than it is in any other animal.

3. The position of the *face* immediately beneath the brain, so that its front is nearly in the same plane as the forehead, is peculiarly characteristic of Man; for the crania of the Chimpanzee and Orang, which approach nearest to that of Man, are entirely posterior to, and not above, the face. It should be remarked that, in the *young* Ape, there is a much greater resemblance to Man in this respect, than there is in the adult; for it is at the time of the second dentition, that the muzzle of the Ape acquires its peculiar elongation, and consequent projection in front of the forehead (Fig. 1); and the whole cast of the features is altered at the same time, so that it approaches much more to that of the lower Quadrumana, than would be supposed from observation of the young animal only.* This increased projection of the muzzle, taken in connection with

* None but young specimens of the Chimpanzee and Orang Outan have ever been brought alive to this country; and they have never long survived the period of their second dentition.

the obliquity of the condyles, is another evidence of want of perfect adaptation to the erect posture; whilst the absence of prominence in the face of Man shows that none but the erect position can be natural to him. For supposing that, with a head formed and situated as at present, he were to move on all-fours, his face would be brought into a plane parallel with the ground; so that as painful an effort would be required, to examine with the eyes an object placed in front of the body, as is now necessary to keep the eyes fixed on the zenith; the nose would then be incapacitated for receiving any other odorous emanations, than those proceeding from the earth or from the body itself; and the mouth could not touch the ground, without bringing the forehead and chin also into contact with it. The oblique position of the condyles in the Quadrumana enables them, without much difficulty, to adapt the inclination of their heads to the horizontal or to the erect posture; but the natural position, in the highest among them, is unquestionably one in which the spinal column is inclined, the body being partially thrown forwards, so as to rest upon the anterior extremities; and in this position, the face is directed forwards without any effort, owing to the mode in which the head is obliquely articulated with the spine.

4. The *vertebral column* in Man, although not absolutely straight, has its curves so arranged, that, when the body is in an erect posture, a vertical line from its summit would fall exactly on the centre of its base. It increases considerably in size in the lumbar region, so as to be altogether somewhat pyramidal in form. The lumbar portion, in the Chimpanzee and Orang, is not of the same proportional strength; and contains but four vertebræ, instead of five. The processes for the attachment of the dorso-spinal muscles to this part, are peculiarly large and strong in Man; and this arrangement is obviously adapted to overcome the tendency, which the weight of the viscera in front of the column would have, to draw it forwards and downwards. On the other hand, the spinous processes of the cervical and dorsal vertebræ, which are in other Mammalia large and strong, for the attachment of the ligaments and muscles that support the head, have comparatively little prominence in Man, his head being nearly balanced on the top of the column.—The base of the human vertebral column is placed on a sacrum of greater proportional breadth, than that of any other animal; this sacrum is fixed between two widely expanded ilia; and the whole pelvis is thus peculiarly broad. In this manner, the femoral articulations are thrown very far apart, so as to give a wide basis of support; and by the oblique direction of the pelvis, the weight of the body is transmitted almost vertically from the top of the sacrum to the upper part of the thigh-bones. The pelvis of the anthropoid Apes is very differently constructed; as will be seen in the adjoining Plate, in which the skeleton of the Orang is placed in proximity with that of Man. It is much larger and narrower; its alæ extend upwards rather than outwards, so that the space between the lowest ribs and the crest of the iliac bones is much less than in Man; their surfaces are nearly parallel to that of the sacrum, which is itself longer and narrower; and the axis of the pelvis is nearly parallel with that of the vertebral column. The position of the human femur, in which its head is most securely retained in its deep acetabulum, is that which it has, when supporting the body in the erect attitude; in the Chimpanzee and



COMPARATIVE VIEW OF THE SKELETON OF MAN, AND THAT OF THE OURAN OUTAN.

Orang, its analogous position is an oblique angle to the long axis of the pelvis, so that the body leans forwards in front of it; in many Mammalia, as in the Elephant, it forms nearly a right angle with the vertebral column; and in several others, as the Horse, Ox, &c. the angle which it makes with the axis of the pelvis and vertebral column is acute. In this respect, then, the skeleton of Man presents an adaptation to the erect posture, which is exhibited by that of no other Mammal.

5. The *lower extremities* of Man are remarkable for their length; which is proportionably greater than that which we find in any other Mammalia, except the Kangaroo tribe. The chief difference in their proportional length, between Man and the semi-erect Apes, is seen in the thigh; and it is from the relative length of this part in him, as well as from the comparative shortness of his anterior extremities, that his hands only reach the middle of his thighs, whilst in the Chimpanzee they hang on a level with the knees, and in the Orang they descend to the ankles. The Human femur is distinguished by its form and position, as well as by its length. The obliquity and length of its neck still further increase the breadth of the hips; whilst they cause the lower extremities of the femora to be somewhat obliquely directed towards each other, so that the knees are brought more into the line of the axis of the body. This arrangement is obviously of great use in facilitating the purely *biped* progression of Man, in which the entire weight of the body has to be alternately supported on each limb; for if the knees had been kept further apart, the whole body must have been swung from side to side at each step, so as to bring the centre of gravity over the top of each tibia; as is seen, to a certain extent in the female sex, whose walk, owing to the greater breadth of the pelvis and the separation between the knees, is less steady than that of the male.—There is a very marked contrast between the knee-joint of Man, and that even of the highest Apes. In the former, the opposed extremities of the femur and the tibia are expanded, so as to present a very broad articulating surface; and the internal condyle of the femur being the longer of the two, they are in the same horizontal plane in the usual oblique position of that bone; so that by this arrangement, the whole weight of the body, in its erect posture, falls vertically on the top of the tibia, when the joint is in the firmest position in which it can be placed. The knee-joint of the Orang, on the other hand, is comparatively deficient in extent of articulating surface; and its whole conformation indicates that it is not intended to serve as more than a partial support.—The Human foot is, in proportion to the size of the whole body, larger, broader, and stronger, than that of any other Mammal save the Kangaroo. Its plane is directed at right angles to that of the leg; and its sole is concave, so that the weight of the body falls on the summit of an arch, of which the os calcis and the metatarsal bones form the two points of support. This arched form of the foot, and the natural contact of the os calcis with the ground, are peculiar to Man alone. All the Apes have the os calcis small, straight, and more or less raised from the ground; which they touch, when standing erect, with the outer side only of the foot: whilst in animals more remote from Man, the os calcis is brought still more into the line of the tibia; and the foot being more elongated and narrowed, only the extremities of the toes come in contact with the ground. Hence Man is the only species of Mammal, which can stand

upon one leg. All the points in which the feet of the anthropoid Apes differ from his, are such as assimilate them to the manual type of conformation, and enable them to serve as more efficient prehensile organs; whilst they diminish their capacity to sustain the weight of the body, when it simply rests upon them.

6. There is a considerable difference in the form of the *trunk*, between Man and most other Mammalia; for his thorax is expanded laterally, and flattened in front, so as to prevent the centre of gravity from being carried too far forwards; and his sternum is short and broad. Between the bony walls of the thorax and the margin of the pelvis, a considerable space intervenes, which is occupied solely by muscles and tegumentary membranes; and these would be quite insufficient to sustain the weight of the viscera, if the habitual position of the trunk had been horizontal.—In these particulars, however, the most anthropoid Apes agree more or less completely with Man.

7. Returning now to the skull for a more minute examination, we observe that the cranium of Man is distinguished from that of the anthropoid Apes, not merely by its great capacity, but also by its smoothness; its surface being almost entirely deficient in those ridges for the attachment of muscles, which are remarkably strong both in the Chimpanzee and Orang, and which impart to its configuration somewhat of a carnivorous character. This aspect is strengthened by the great depth of the temporal fossa, and by the extent and strength of the zygomatic arch; features that are most remarkably developed in the *Troglodytes gorilla*, a newly-discovered species of Chimpanzee, which is regarded by Prof. Owen as presenting on the whole the nearest approach to the human type. Moreover, the jaws in even the most degraded races of Man project far less from the general plane of the face, than they do in the Apes; and his teeth are arranged in a continuous series, without any hiatus or any considerable difference in length, whilst all the Apes, in their adult state at least, are furnished with canine teeth of extraordinary length, between the sockets of which and those of the adjoining teeth (in front in the upper jaw, and behind in the lower,) there is a vacant space or diastema. Even in the most prognathous Human skulls, moreover, the incisors meet each other much more nearly in the same axis than they do in the anthropoid Apes, in which they form an angle with each other that is not nearly so divergent. The fusion of the intermaxillary or premaxillary bones with the superior maxillary, at an early period of fœtal life, is a remarkable character of the Human cranium, as distinguishing it from that of the Apes, in which the intermaxillary bones remain separate to a much later period; sometimes differing also, in a very marked degree, in size and shape. Thus in the *Troglodites gorilla*, these bones are not only remarkable for their prominence, but also for their upward extension round the nostrils, so that they completely exclude the maxillary bones from their borders, and form the bases of support for the nasal bones; and although they coalesce with the maxillaries at and near the alveolar portion, they remain separate elsewhere. The lower jaw of Man is remarkable for that prominence at its symphysis, which forms the chin; and although this, also, is least developed in the most prognathous human crania, yet it is never so deficient as it is in the lower jaw of the Chimpanzee and Orang.

—It is curious to observe that the skulls of the *young* of Man and of the anthropoid Apes resemble one another much more than do those of the *adults;* each tending to diverge, in its advance towards full development, from a type which seemed almost similar in both. It is only after their second dentition, that the anthropoid Apes present those cranial characters which peculiarly tend to degrade them towards the truly quadrupedal type; and in the Human subject we see that in the advance from childhood to adult age, there is a progressive enlargement of the face, in proportion to the capacity of the cranial cavity.*

8. The great size of the cranial portion of the skull in Man, as compared with the facial, produces a marked difference between his facial angle, and that of even the highest Quadrumana. According to Camper, who first applied this method of measurement, the facial angle of the average of European skulls is 80°, whilst in the ideal heads of the Grecian gods it is increased to 90°; on the other hand, in the skull of a Kalmuck he found it to be 75°; and in that of a Negro only 70°; and applying the same system of measurement to the skulls of Apes, he found them to range from 64° to 60°. But these last measurements were all taken from young skulls, in which the forward extension of the jaws, which takes place on the second dentition, had not yet occurred. In the adult Chimpanzee, as we learn from the measurements of Prof. Owen, the facial angle is no more than 35°, and in the adult Orang only 30°; so that instead of the Negro being nearer to the Ape than to the European, as Camper's estimate would make him, the interval between the most degraded Human races and the most elevated Quadrumana is vastly greater than between the highest and the lowest forms of humanity. It must be borne in mind that the facial angle is so much affected by the degree of prominence of the jaws, that it can never afford any certain information concerning the elevation of the forehead and the capacity of the cranium; all that it can in any degree serve to indicate, being the relative proportion between the facial and the cranial parts of the skull.

9. The most characteristic peculiarity of the Human *Myology*, is the great development of those muscles of the trunk and limbs which contribute to the maintenance of the erect posture. Thus, the gastrocnemii, and the other muscles which tend to keep the leg erect upon the foot, form a much more prominent 'calf' than is seen either in the most anthropoid Apes, or in any other animal. So, again, the extensors of the leg upon the thigh are much more powerful than the flexors; a character which is peculiar to man. The glutæi, by which the pelvis is kept erect upon the thigh, are of far greater size than is elsewhere seen. The superior power of the muscles tending to draw the head and spine backwards, has been already referred to. Among the differences in the attachment of individual muscles, it may be noticed that the flexor longus pollicis pedis proceeds in Man to the great toe alone, on which the weight of the body is often supported; whilst it is attached in the Chimpanzee and Orang to the three middle toes also. The latissimus dorsi is destitute in Man of that prolongation attached to the olecranon,

* See Prof. Owen's Papers on the Anatomy of the Orang and Chimpanzee, in the "Zoological Transactions," vols. i. and iii.; and Prof. Vrolik in the Art. *Quadrumana* in the "Cyclopædia of Anatomy and Physiology," vol. iv.

which is found in the lower Mammalia, and which exists even in the Chimpanzee, probably giving assistance in its climbing operations. The larger size of the muscles of the thumb, is, as might be expected, a characteristic of the hand of Man; although the number of muscles by which that digit is moved, is the same in the Chimpanzee, as in the Human subject. The existence of the extensor digiti indicis, however, as a distinct muscle, is peculiar to Man.

10. The *Visceral* apparatus of Man presents very few characteristic peculiarities, by which it can be distinguished from that of the higher Quadrumana; among the most remarkable is the absence of the laryngeal pouches, which exist even in the Chimpanzee and Orang Outan, as dilatations of the laryngeal ventricles. — Of the anatomy of the last-named animals in their *adult* condition, however, we know as yet too little to enable its conformity to that of Man to be confidently pronounced upon.

11. The *Brain* of Man does not differ so much in conformation from that of the Chimpanzee and Orang, as the superiority of his mental endowments might have led us to anticipate. The following are the principal differences which it seems to present:—1. The mass of the entire brain is considerably larger in proportion to that of the body, and in proportion also to the diameter of the nerves which are connected with it.—2. In the external configuration of the Cerebrum, we notice that the *posterior* lobes are more developed, so as to project further beyond the Cerebellum than they do in any of the Quadrumana; the convolutions are more numerous, and the sulci are deeper.—3. On examining the internal structure, it is found that the peripheral layer of grey matter is thicker, the corpus callosum extends further backwards, and the posterior cornua of the lateral ventricles are relatively longer and larger than they are in any Quadrumana.—4. The Cerebellum, also, is proportionally larger.

12. The small size of the face of Man, compared with that of the cranium, is an indication that in him the *senses* are subordinate to the *intelligence*. Accordingly we find that while he is surpassed by many of the lower animals in acuteness of sensibility to light, sound, &c. he stands pre-eminent in the power of comparing and judging of his sensations, and of drawing conclusions from them as to their objective sources. Moreover, although none of his senses are very acute in his natural state, they are all moderately so; and they are capable of being wonderfully improved by practice, when circumstances strongly call for their exercise. This seems especially the case with the *tactile* sense, of which Man can make greater use than any other animal, in consequence of the entire freedom of his anterior extremities; although there are many which surpass him in their power of appreciating certain classes of tactile impressions.—So, again, Man's nervo-muscular power is inferior to that of most other animals of his size; the full grown Orang, for example, surpasses him both in strength and agility; and the larger Chimpanzee, according to the statements of the Negroes who have encountered it, is far more than a match for any single man, and is almost certain to destroy any human opponent once within his grasp.—The absence of any natural weapons of offence, and of direct means of defence, are remarkable characteristics of Man, and distinguish him not only from the lower Mammalia,

but also from the most anthropoid Apes; in which it is obvious (both from their habits and general organization) that the enormous canines have no relation to a carnivorous regimen, but are instruments of warfare. On those animals to which Nature has denied weapons of attack, she has bestowed the means either of passive defence, of concealment, or of flight; in each of which Man is deficient. Yet, by his superior reason, he has not only been enabled to resist the attacks of other animals, but even to bring them into subjection to himself. His intellect can scarcely suggest the mechanism which his hands cannot frame; and he has devised and constructed arms more powerful than those which any creature wields, and defences so secure as to defy the assaults of all but his fellow-men.

13. Man is further remarkable for his power of adaptation to varieties in external condition, which renders him to a great extent independent of them. He is capable of sustaining the highest as well as the lowest extremes of temperature and of atmospheric pressure. In the former of these particulars, he is strikingly contrasted with the anthropoid Apes; the Chimpanzees being restricted to the hottest parts of Africa, and the Orang Outan to the tropical portions of the Indian Archipelago; and neither of these Animals being capable of living in temperate climates without the assistance of artificial heat, even with the aid of which they have not hitherto survived their second dentition. So, again, although Man's diet seems naturally of a mixed character, he can support himself in health and strength either on an exclusively vegetable diet, or, under particular circumstances, on an almost exclusively animal regimen.

14. The slow growth of Man, and the length of time during which he remains in a state of dependence, are peculiarities that remarkably distinguish him from all other animals. He is unable to obtain his own food, during at least the first three years of his life; and he does not attain to his full bodily stature and mental capacity, until he is more than twenty years of age. This retardation of the developmental process seems to have reference to the high grade which it is ultimately to attain; for everywhere, throughout the Organized Creation, do we observe that the most elevated forms are those which go through the longest preparatory stages, and of which the evolution is most dependent upon the assistance afforded by the parental organism during its earlier periods. The peculiar prolongation of this state of dependence in the Human species, has a most important and evident effect upon the social condition of the race; being, in fact, the chief source of family ties, and affording the opportunity for the education which transmits to the rising generation the influence of the intellectual culture and moral training of the past.

15. Still, however widely Man may be distinguished from other animals by these and other particulars of his structure and economy, he is yet more distinguished by those *mental* endowments, and by the habitudes of life and action thence resulting, which must be regarded as the essential characteristics of humanity. It is in adapting himself to the conditions of his existence, in providing himself with food, shelter, weapons of attack and defence, &c., that Man's intellectual powers are first called into active operation; and when thus aroused, their development has no assignable limit. The Will, guided by the intelligence, and acted-on by the desires and emotions, takes the place in Man of the Instinctive propensities which are the usual springs of action in the lower animals; and although,

among the most elevated of these, the intelligent will is called into exercise to a certain extent, yet it never acquires among them the dominance which it possesses in Man, and the character never rises beyond that of the child. In fact, the correspondence between the psychical endowments of the Chimpanzee, and those of the Human infant before it begins to speak, is very close. The *capacity for intellectual progress* is a most remarkable peculiarity of Man's psychical nature. The instinctive habits of the lower animals are limited, are peculiar to each species, and have immediate reference to their bodily wants. Where a particular adaptation of means to ends, of actions to circumstances, is made by an individual, the rest do not seem to profit by that experience; so that, although the instincts of particular animals may be modified by the training of Man, or by the education of circumstances, so as to show themselves after a few generations under new forms, no elevation in intelligence appears ever to take place spontaneously, no psychical improvement is manifested in the species at large.—One of the most important aids in the use and development of the Human Mind, is the capacity for *articulate speech;* of which, so far as we know, Man is the only animal in possession. There is no doubt that many other species have certain powers of communication between individuals; but these are probably very limited, and of a kind more allied to "the language of signs," than to a proper verbal language. In fact, it is obvious that the use of a language composed of a certain number of distinct sounds, combined into words in a multitude of different modes, requires a certain power of abstraction and generalization, in which it appears that the lower animals are altogether deficient. So, again, verbal language affords the only means whereby abstract ideas can be communicated; and those who have perused the interesting narrative given by Dr. Howe of his successful training of Laura Bridgeman, will remember how marked was the improvement in her mental condition, from the time when she first apprehended the fact that she could give such expression to her thoughts, feelings, and desires, as should secure their being comprehended by others.

16. This capacity for progress is connected with another element in Man's nature, which it is difficult to isolate and define, but which interpenetrates and blends with his whole psychical character. "The soul," it has been remarked, "is that side of our nature which is in relation with the infinite;" and it is the existence of this relation, in whatever way we may describe it, which seems to constitute the distinctive peculiarity of Man. It is in the desire for an improvement in his condition, occasioned by an aspiration after something nobler and purer, that the main-spring of human progress may be said to lie; among the lowest races of mankind, the capacity exists, but the desire seems dormant. When once thoroughly awakened, however, it seems to "grow by what it feeds on;" and the advance once commenced, little external stimulus is needed; for the desire increases at least as fast as the capacity. In the higher grades of mental development, there is a continual looking upwards, not (as in the lower) towards a more elevated human standard, but at once to something beyond and above man and material nature. This seems the chief source of the tendency to believe in some unseen existence; which may take various forms, but which seems never entirely absent from any race or nation, although, like other innate tendencies, it may be deficient in indi-

viduals. Attempts have been made by some travellers to prove that particular nations are destitute of it; but such assertions have been based only upon a limited acquaintance with their habits of thought, and with their outward observances; for there are probably none who do not possess the idea of some invisible Power, external to themselves, whose favour they seek, and whose anger they deprecate, by sacrifice and other ceremonials. It requires a higher mental cultivation than is commonly met with, to conceive of this Power as having a Spiritual existence; but wherever the idea of spirituality can be defined, this seems connected with it. The vulgar readiness to believe in ghosts, demons, &c. is only an irregular or depraved manifestation of the same tendency. Closely connected with it is the desire to participate in this spiritual existence, of which the germ has been implanted in the mind of Man, and which, developed as it is by the mental cultivation that is almost necessary for the formation of the idea, has been regarded by philosophers in all ages as one of the chief natural arguments for the immortality of the soul. By this immortal soul Man is connected with that higher order of being, in which Intelligence exists, unrestrained in its exercise by the imperfections of that corporeal mechanism through which it here operates; and to this state,—a state of more intimate communion of mind with mind, and of creatures with their Creator,—he is encouraged to aspire, as the reward of his improvement of the talents here committed to his charge.

## CHAPTER II.

### OF THE CHEMICAL COMPONENTS OF THE HUMAN BODY, AND THE CHANGES WHICH THEY UNDERGO WITHIN IT.

17. The body of Man, like that of every other Organized being, is composed of elementary substances that exist abundantly in the Inorganic Universe, in the midst of which it is placed; and it is from that Universe, that all its materials are derived, either directly or indirectly. The atmosphere supplies the Plant with water, carbonic acid, and ammonia; and at the expense of the oxygen, hydrogen, carbon, and nitrogen which it appropriates from these simple binary compounds, the Plant generates certain peculiar substances, of more complex composition, which are applied in the first place to the extension of its own structure, but which are destined afterwards to constitute the materials of Animal nutrition. On the other hand, the Animal, availing itself of these supplies, gives back to the Inorganic world, not only by the decay of its body after death, but also by the continual decomposition taking place in it during life, the elements which the Plant had withdrawn; and this, for the most part, in the very forms in which they were originally combined, viz. water, carbonic acid, and ammonia. Most Plants also take up mineral substances of some kind from the soil, which are united more or less closely with the organic compounds formed by them, and which enter with these into the bodies of Animals; to be in like manner restored to the earth beneath them, by the decay of the organisms of which they have formed part.—As this remarkable sequence has been more fully traced out elsewhere,*

* See the Author's "Principles of Physiology, General and Comparative," CHAP. V.

and as the Physiologist has much less to do with the Ultimate components of the Animal body, than he has with the Organic Compounds which are supplied to it as nutriment and of which its fabric is composed, it will not be requisite to dwell any longer upon this part of the subject; and we may at once pass on to consider the nature and properties of these compounds, and to inquire into the metamorphoses which they undergo within the living system. In doing this, it would seem most appropriate to adopt a classification primarily founded rather upon their *physiological* than upon their purely *chemical* relations,—upon the position they hold in the vital economy, rather than upon their ultimate composition or their resemblances to inorganic compounds. We should thus be led to arrange them in four principal groups:—

I. The *histogenetic* substances, which have been introduced into the body as the materials of its fabric, or are generated from these compounds subsequently to their introduction into it, and are on their way to become part of its organized structure by *progressive metamorphosis.* These are either *organic* or *inorganic* compounds; and of the former, all, save fatty matters, belong to the *azotized* or *nitrogenous* group.

II. The *calorific substances*, which are either introduced into the body as components of the food, or which are formed within it,—by the metamorphosis either of the histogenetic substances, or of the components of the tissues themselves;—these substances are all of the *saccharine* or of the *oleaginous* class, or are derivable from them by very simple transformations.

III. The *components of the actual living tissues.*

IV. The *excrementitious substances,* which are formed within the body as the *products of the disintegration and retrograde metamorphosis of its tissues*, and which are on their way from these to the outlets of the excretory apparatus;—these constituting a group intermediate in their chemical character between the foregoing and inorganic matter.

It is to be observed, however, that in this classification (as in every other assemblage of natural objects) the different groups are connected together by intermediate links, which render it impossible to isolate them completely. Thus, fatty matters must be looked upon as histogenetic substances, since they seem essential to the production of almost all the tissues, and enter largely into the composition of the adipose and nervous; yet their production within the body seems to have most immediate reference to the demand set up by the combustive process, in which a far larger quantity is daily consumed, than can be required for the maintenance of the organized fabric. So, again, fat *as such* must be regarded as a component of the actual living tissues, and therefore as belonging to the third class; but it does not, like the histogenetic substances, undergo organization, being simply combined mechanically with the other components, and being capable of ready separation from them by no other than mechanical means. On the other hand, although the third class may be regarded as, in great measure, *chemically* identical with the first, yet the *molecular condition* of their respective components is very different; for the properties of the living tissues cannot be chemically examined, until they have been deprived of all those characters which distinguish them as organized substances, and are reduced back to a state resembling that in which they are first taken into the body. Here again, however, we

meet with a link of transition; for fibrin, which ranks as one of the histogenetic substances, may be almost regarded as "liquid flesh" (§ 24), and as therefore deserving of a place in the third class. And lastly, the fourth class of substances is connected with the third by this circumstance, that the excrementitious substances are separated from the blood into which they have been received back, by the agency of glandular structures, of whose organized tissues they form part for a time, as fat does of adipose tissue: whilst, again, they are connected with the second by the fact, that a considerable part of the products of disintegration is made use of as calorific material, being converted within the body into saccharine and oleaginous substances in all respects resembling those taken-in as food.—It will, therefore, be found convenient to modify the above classification, by arranging the substances which it includes in some degree according to their Chemical characters, still keeping in view, however, their physiological destination. Thus we shall consider in the 1st place the substances of the *Albuminous* type, or "protein-compounds," both as the *materials for*, and as the *components of*, the living tissues; and 2ndly, those of the *Gelatinous type*, under the same aspects. From these we shall pass, 3rdly, to the *Oleaginous* group, of which the chief constituents may be ranked both as *histogenetic* and as *calorific* substances, while some members of it should probably rank also as *products of disintegration:* and in connection with these will be described, 4thly, the *Saccharine* matters, which are also in part to be regarded as products of disintegration, and which are more exclusively calorific than the oleaginous, being never applied to the formation of tissue save through conversion into fatty compounds. In the 5th place, we shall pass under review the most notable of those *metamorphic forms,* under which the components of the tissues present themselves in the principal Excretions. And lastly we shall notice the *Inorganic Constituents,* which, with the preceding, enter into the composition of the Human fabric.*

## 1. *Albuminous Compounds.*

18. Under this head may be grouped together a series of organic compounds, which are of primary importance in *histogenesis* or the formation of tissue; and this not less in the Vegetable kingdom than in the Animal; the original cell-walls of the Plant, as well as those of the Animal, being formed at their expense.† Putting aside those Albuminous substances which are proper to the Vegetable kingdom, and restricting ourselves to those which are parts of the Animal body or are formed within it, we find this group to consist of *Albumen,* which may be taken as its type, with Casein, Globulin, and Fibrin; these are also generally known under the designation of "Protein-compounds;"‡ and the following properties are for the most part common to them all.—They occur in two

* In the following outline, the authority principally relied upon will be the "Physiological Chemistry" of Prof. Lehmann, of which a Translation (by Prof. G. E. Day) is now in course of publication by the Cavendish Society.

† See "Principles of Physiology, General and Comparative," § 136.

‡ Although this designation was first given them by Mulder under an idea (which has since proved to be erroneous) that he could obtain from either of them a certain organic base, free from sulphur and phosphorus, to which he gave the name of *Protein,* yet it has been found to be so convenient both in Chemistry and Physiology, that there seems to be a general accordance in its retention. See Lehmann's "Physiological Chemistry," vol. i. p. 326.

conditions, namely in a *soluble*, and in an *insoluble* or scarcely soluble state; it is in the former condition that we find them naturally existing in the animal fluids. The soluble modification, when dried, forms a faint yellow, translucent, friable mass, having no smell or peculiar taste; it dissolves in water, but is insoluble in alcohol and ether; it is precipitated by alcohol from the aqueous solution, after which it is usually insoluble in water. The aqueous solution is precipitated by most metallic salts, and the precipitate generally contains the acid and base of the salt employed, in addition to the protein-compound. The greater number cannot be precipitated from their aqueous solution by alkalies, or by most of the vegetable acids; but they are precipitated by mineral acids (with the exception of ordinary phosphoric acid) and by tannic acid; and by some of these they are converted into their insoluble form. Into this, moreover, the greater number of them are changed by boiling; and it is in this mode that their insoluble forms are commonly obtained.—The insoluble compounds, when dried, are white and pulverizable, without taste or smell, without reaction on vegetable colours, and insoluble in water, alcohol, ether, and all indifferent menstrua; but they are all more or less readily dissolved by *alkalies*, from which they may be precipitated by mere neutralization with acids. Their behaviour towards different *acids* is by no means so uniform, and must be separately described in each case. All of them, however, are acted-on in a peculiar manner by concentrated Nitric and Hydrochloric acids; the former giving them when heated a deep *lemon-coloured* tint; whilst the latter causes them to assume a gradually-increasing *blue* colour, which becomes intense when they are exposed to warmth and air. Again, they are all dissolved by concentrated acetic acid and other organic acids, as well as by phosphoric acid; and are precipitated from these solutions by ferrocyanide of potassium.—All the protein-compounds contain Sulphur, which seems to be one of their essential constituents, not being capable of entire separation without the complete destruction of the organic substance, although a part may be withdrawn by digestion with fixed alkalies.

19. All the Protein-compounds are very liable to decomposition; this change taking place in them spontaneously, when they are exposed to the air at ordinary temperatures; and being very readily induced by oxidising agents, alkalies, &c. the effect of which is promoted by heat. As yet, however, no satisfactory clue has been obtained to the very complex composition of these substances; since they cannot be resolved by analysis (like complex inorganic bodies) into two or more compounds whose synthesis reproduces the original. Still it is very interesting to observe, that whilst the ultimate decomposition of the protein-compounds resolves them (with oxygen taken from the atmosphere) into water, carbonic acid, and ammonia, various organic compounds may be generated by a less complete separation of their components. Thus by the action of oxidising substances, the formic, acetic, butyric, caproic, and other organic acids of the same group, which occur naturally in the animal body, may be obtained; and there is a strong probability that the ordinary fatty acids may be generated by a similar change (§ 40).—Again, by the prolonged action of caustic alkalies upon the protein-compounds, a crystalline substance is obtained, which is termed *Leucine;* this forms colourless scales, destitute of taste and odour; it is soluble in water, and

sublimes unchanged. It consists of 12 C, 12 H, 1 N, 4 O. There is not at present any evidence that this substance is ever produced in the living body; but a strong interest attaches to it, from the fact that it may be procured from Gelatine, as well as from the Protein-compounds. Another compound obtained by the same reaction is called *Tyrosine;* it crystallizes in brilliant needles; and its formula is 16 C, 9 H, 1 N, 5 O.—The tendency to decomposition which exists in this class of substances, not merely occasions the re-arrangement of their own elements in new compounds of a different character, but also tends to produce similar changes in other substances; and it is probable that this kind of agency takes place to a great extent in the living body. Thus, a protein-compound in a certain stage of decomposition will convert starch into sugar; in a more advanced state of change, it will convert sugar into lactic acid, mannite, and vegetable mucus, or into alcohol and carbonic acid; and by the same agency, lactic acid may be resolved into butyric acid, hydrogen, and carbonic acid.* This property of exciting change in other substances, whilst themselves passing into decay, makes it very important that the history of the protein-compounds in the living body should be fully made out; since it is obvious that they are not merely required as histogenetic materials, but that they also take an important part in the transformation of other substances by their action as *ferments.*

20. Of the whole series of protein-compounds, *Albumen* is obviously the one which may be considered as the proper *pabulum* of the Animal tissues generally; since we have evidence that from it, in combination with fatty matter and mineral ingredients, all the tissues of the body may be generated. The store of nutriment laid up within the egg, from which in due time the chick is developed, with its bones, muscles, nerves, tendons, ligaments, membranes, skin, horny bill, feathers, &c. is composed of nothing else; and the albumen of the blood of the adult animal is continually being withdrawn from it, to be applied in like manner to the maintenance of these various tissues.† We shall find, moreover, that the other histogenetic substances, when employed as food, must be reduced to the state of albumen, before they can be appropriated by the living system. The properties of Albumen may be studied in the white of the egg, or in the serum of the blood, from either of which situations it may be obtained in a nearly pure state by very simple means. These two forms of it, however, are not precisely identical; indeed it appears from recent inquiries, that striking differences are produced in albumen, not merely by the presence of some other body, such as an alkali or a salt, but by the different proportions in which this occurs; and hence it is that various and contradictory statements have been made, in reference to the properties of this substance. The following are the facts of most physiological interest.—In the before mentioned animal fluids, as well as in several others, Albumen exists in its soluble form, but not in an isolated state; for it is united with soda as an acid to its base, and thus may be formed a basic, neutral, or acid albuminate of soda. The *basic* compound, which contains about $1\frac{1}{2}$ per cent of soda, and gives a slightly

* See Prof. Liebig's "Familiar Letters on Chemistry," 3rd ed. p. 207.

† Even if it should be proved that the Gelatigenous tissues are ever formed from Gelatin taken-in as food, which the Author believes to be highly improbable (see § 35), yet there can be no question that they are formed from the albuminous part of the blood, when (as in all Herbivorous animals) the aliment contains no gelatinous component.

alkaline reaction, is the one which ordinarily presents itself in normal blood, as well as in the egg; but diseased blood (as first ascertained by Scherer) very frequently contains a *neutral* albuminate, the characteristic of which is, that its solution becomes turbid on the simple addition of water; and it has been shown by Lehmann that this occurs normally in the blood of the hepatic and splenic veins, that of the former having been deprived of a portion of its alkali whilst passing through the liver, and that of the latter having received an additional charge of its acid in the splenic parenchyma.—The ordinary basic albuminate of soda, or sodo-albumen, is far more soluble in water than is pure albumen, which, indeed, when *entirely* separated from all other substances, is probably not soluble at all. It differs from pure albumen, moreover, in the mode in which it coagulates on the application of heat; for whilst the latter separates in flakes, sodo-albumen forms a white gelatinous mass, or, if the fluid be much diluted, makes itself apparent only by a milky or opalescent turbidity. The alkaline reaction of a solution of sodo-albumen becomes more marked on boiling, which indicates that at least a portion of the alkali must be separated from the albumen on its coagulation; and according to Prof. Liebig (op. cit. p. 387, note), a new compound of albumen with phosphoric acid and lime is then probably formed. A moderately strong solution of pure albumen in water becomes turbid at 140°, becomes completely insoluble at 145°, and separates in flakes at 167°; when excessively diluted, however, no turbidity can be produced by a less heat than 194°; and coagula will only separate after it has been boiled a considerable time. After having been dried *in vacuo*, however, or at a temperature below 120°, Albumen may be heated to 212° without passing into the insoluble condition.* Albumen may be precipitated from an aqueous solution by diluted alcohol; but it does not pass into the insoluble form, unless a large quantity of strong alcohol be added. It is also precipitated by creosote. Albumen is converted into the insoluble form by most acids; but it is not precipitated by the mineral acids, unless they are added in excess; and the organic acids, with the exception of the tannic, do not throw it down. It is converted into the insoluble form by alkalies, but is not precipitated by them, being held up by their presence. The greater number of metallic salts precipitate albumen, which generally passes into the insoluble state, and enters into combination, either with the basic salt itself, or with its acid and its base separately; one of these salts, the albuminate of the chloride of mercury, is of much interest, as being that which is produced by the mixture of a solution of albumen with one of corrosive sublimate.—The following is the composition of Albumen, according to the most recent analyses of two eminent chemists.

| | Scherer. | Mulder. |
|---|---|---|
| Carbon | 54·9 | 53·5 |
| Hydrogen | 7·0 | 7·0 |
| Nitrogen | 15·7 | 15·5 |
| Oxygen | 22·4 | 22·0 |
| Sulphur | | 1·6 |
| Phosphorus | | 0·4 |
| | 100·0 | 100·0 |

* This fact is of much interest in relation to the experiments of Doyère and others upon the tenacity of life of the Tardigrade tribe of Rotifera; for it has been found that, *when*

It has lately been affirmed, however, by Prof. Liebig, that Phosphorus is not (like Sulphur) a true constituent of Albumen, or of any of the Protein-compounds; and that it has no existence in any article of food, or in any tissue of the body, save in combination with oxygen as phosphoric acid.* Albumen seems never to occur in the animal body, except in such intimate union with fatty and mineral substances, that it is with difficulty separated from them. The quantity of these is variable; but altogether they usually amount to at least 6 per cent, of which from 1 to 2·5 per cent consists of phosphate of lime.

21. As a general rule, Albumen is found in all the *nutritive fluids* of the body, as the Blood, the Chyle, the Lymph, and the serous exudation which percolates through the interstices of the tissues. From several of the *tissues*, also, it may be obtained in considerable abundance; but it is not always easy to say whether it is a natural constituent of such tissues, or whether it is simply left by the fluid with which they were charged. It has been recently affirmed by Prof. Liebig, however, that the characteristic solid constituent of Muscle, which has been usually known under the designation of *fibrin*, is in reality essentially conformable in all its chemical relations with coagulated Albumen; and is at any rate much more nearly allied to it, than it is to the fibrin of the blood. And if this be true, it is probable that the same may be said of the *walls* of the component cells of the glandular, nervous, adipose, epidermic, and other tissues, however different may be the character of their contents; and that Albumen is, in fact, the fundamental constituent of all such tissues as do not belong to the gelatinous type. It cannot be said that Albumen is a normal constituent of any of the *secreted* fluids, such as the salivary, gastric, or pancreatic; the peculiar organic constituents of these being apparently albuminous substances in a state of change. And among the proper *excretory* matters, it is certain that albumen is never found but in consequence of morbid action; its appearance indicating either disease of the excreting organ, or a marked alteration either in the composition of the blood or in the mode of its circulation.

22. The place of Albumen is occupied in Milk by the substance termed *Casein*, which seems to differ from it less in ultimate composition, than it does in chemical properties. Casein, like albumen, occurs in the soluble and insoluble states; but the passage from one to the other takes place under different conditions. It appears from the late researches of Scherer and Rochleder, that *pure* Casein is insoluble in water, and that the soluble casein is a combination of pure casein with an alkaline or earthy base, the withdrawal of which is the cause of its precipitation by acids.† In this precipitation, the casein is not reduced to its insoluble form; as, by neutralizing the acids with alkalies or metallic oxides, it again dissolves. Casein is not (like Albumen) made to coagulate from its ordinary state of solution by the agency of heat; and the precipitate thrown down by the addition of a small quantity of alcohol, is readily dissolved again in water. The most characteristic distinctions between Albumen and Casein, however, are afforded by the peculiar action of the

*completely desiccated*, the bodies of these animals might be exposed to a heat of 250°, without the destruction of their vitality. See "Principles of Phys., Gen. and Comp.," § 65.

* See his "Familiar Letters on Chemistry," pp. 437 and 451.

† See the Memoir of Dr. Panum, hereafter cited.

lactic and acetic acids, and of the "rennet" of the calf's stomach, upon the latter; for Casein is very readily precipitated by those acids, although they do not form combinations with it, and it is made to coagulate by contact with an excessively small portion of rennet; whilst neither of these reagents has any effect upon ordinary Albumen.*—The analyses given by different chemists of the ultimate composition of Casein, differ quite as much from each other, in regard to the proportions of Oxygen, Hydrogen, Carbon and Nitrogen, which it contains, as they do from the analyses of Albumen already cited; and the only positive diversity between the two substances, that can be detected by ultimate analysis, seems to be in the absence of phosphorus from casein, and in the smaller proportion of sulphur which it includes.—Casein, like albumen, never occurs in nature in an isolated form, but is intimately blended with other substances; and it is specially remarkable for the quantity of Phosphate of Lime which is incorporated with it, as much as 6 per cent of this earthy salt being usually obtainable from it.—It is in the milk of the Mammalian female, that we meet with Casein in the greatest abundance; and it must be formed in that secretion either from the albumen of her blood, or at the expense of her solid tissues. When introduced as food into the stomach of her offspring, it is there completely coagulated, and seems to be reduced back in the digestive process to the condition of Albumen, as it also is when used as food in its coagulated state by the adult. Casein has been obtained in considerable quantity from the blood of puerperal women, in whom the secretion of milk has been checked; but it seems doubtful if true casein is ever a normal constituent of the blood. Various experimenters have affirmed its presence; but their results do not for the most part seem trustworthy, since they are invalidated by certain fallacies which have been pointed out by Prof. Lehmann (Op. cit. vol. i. p. 380). The existence of Casein in ordinary blood-serum has been more recently affirmed by Dr. Panum; but his experiments are scarcely satisfactory, since it appears by no means impossible that what he represents to be Casein may be nothing else than the neutral albuminate of soda (§ 20), which is precipitated, as we have seen, by the addition of water, and which may also be thrown down by acetic acid.†—It is interesting to remark,

* It is shown by Prof. Lehmann, however, that under certain circumstances Albumen may be precipitated by acetic acid; and that even the rennet-test is liable to fallacies. It is very commonly supposed that the coagulation of Casein in milk, when treated with rennet, is due to the action of rennet as a ferment upon the sugar of milk, the lactic acid thus formed being the real precipitant of the casein. The experiments cited by Prof. Lehmann, however, render it probable that the action of rennet upon casein does not require the intermediation of lactic acid. (Op. cit. pp. 375–381.)

† It has been ascertained by Dr. Panum, that pure Casein from milk is readily soluble in water containing a certain quantity of phosphate of soda, but is precipitated when this solution is too much diluted; and this fact he applies to the explanation of the turbidity which he has found to be frequently produced in ordinary blood-serum by the addition of acetic acid, or by dilution with water, or by both means combined; this reaction being supposed by him to take place under the following conditions.—The (supposed) Casein, united with soda, is held in solution by the salts which are present, especially phosphate of soda; if its quality be very large, the solvent power of the salts is sufficiently weakened by the addition of water to occasion its precipitation; and the addition of acetic acid, without dilution, will produce the same effect by withdrawing its soda; but if its quantity be smaller, its precipitation can only be accomplished by the dilution of the solution, and the addition of acetic acid, conjointly.— See Dr. Panum's Memoir in the "Bibliothek for Læger" for Jan. 1850, and the "London Journal of Medicine," July, 1850.

however, that from the later inquiries of Prof. Lehmann, it seems by no means improbable that the *Vitellin*, which forms the albuminous body of the yolk of the egg, and which has been described as a peculiar compound intermediate between albumen and fibrin, is in reality a mixture of Albumen with Casein. "The amorphous dark granules of the yolk," he says, "are pure casein free from alkali, which, like ordinary casein, is rich in phosphate of lime; while in the proper intercellular fluid of the yolk, there is no casein, but merely dissolved albumen poor in alkali." On shaking fresh yolk with ether and water, there is formed under the yellow fatty stratum of ether, a white and somewhat viscid mass, which has been mistaken for Vitellin coagulated by ether; but if this substance be carefully separated by filtration and washing, it is found to bear a perfect resemblance to pure casein, answering to all the casein-tests (including that of rennet), and merely containing additionally a little albumen poor in salts.*

23. Nearly allied to Albumen, and differing from it rather in its physiological than in its chemical relations, is another substance which is largely present in the Human body; namely *Globulin*. This is one of the constituents of the red blood-corpuscles, and is also found in the peculiar cells of the crystalline lens; and is probably to be regarded as albumen somewhat changed by the peculiar action of these bodies. It cannot be certainly shown to differ from Albumen in ultimate composition, except that (like Casein) it contains no phosphorus; but it is not coagulated by heat with nearly the same facility, whilst, on the other hand, it is readily precipitated by acetic acid. In these respects, Globulin may be considered as intermediate between Albumen and Casein; and it seems further to correspond with the latter substance, in being quite insoluble in water when detached from all its combinations, being only held in solution by union with an alkali, or by the presence of phosphate of soda. In its coagulated state, it cannot be distinguished from other protein-compounds. The quantity of saline matter usually combined with globulin seems to be small; the soluble salts amounting to about 1·5 per cent. and the phosphate of lime to no more than 0·25 per cent.

24. The substance known as *Fibrin* is almost as closely accordant with Albumen, as are the foregoing, in regard to its ultimate composition and its purely *chemical* relations; but it differs widely in its *physiological* characters, which are such as distinctly indicate that it possesses properties of a different nature from its chemical and physical attributes, and deserving to be ranked as *vital*. Neither Albumen, nor any other of the protein-compounds already described, presents the slightest tendency to pass spontaneously into any condition that presents the least trace of organization; the masses formed by their coagulation, in whatever way this may have been brought about, being mere aggregations of amorphous particles, entirely destitute of *structure*. But it is the characteristic property of Fibrin, that although existing in solution in certain animal fluids, so long as they are contained within the living vessels, it tends to separate itself in the solid form, that is, to coagulate spontaneously, when no longer subjected to vital influence, as when withdrawn from the living body, or when the body itself dies; and further, that the coagulum, when formed under favourable circumstances, exhibits a definite organic structure, of a

* "Lehrbuch der physiologischen Chemie," band ii. p. 349.

very simple kind indeed, but such as closely resembles that of tissues which form a large part of the animal fabric.—This substance is one, consequently, of great physiological importance. It is found in all fluids that are being applied to the nutrition of living tissues, or are in immediate preparation for that purpose: thus it is one of the most characteristic ingredients of the Blood; it also presents itself in Chyle and Lymph; and it is a component of all those exudations which are designated as 'plastic,' from their tendency to give origin to new tissues. On the other hand, it is entirely absent from all the normal secreted fluids, whether these are destined for special uses within the body, or are to be carried forth and discharged as the products of its decay. All these circumstances seem to point very decidedly to the conclusion, that Fibrin is to be considered as *a histogenetic substance in the act of conversion* into living tissue, its molecules having a tendency to assume one of the peculiar arrangements which is characteristic of organization. Whether *all* Albuminous substances, however, must pass through the condition of Fibrin, before they can be applied to the purposes of nutrition, is a question which cannot as yet be determined; and it is safer, in the present state of our knowledge (or rather of our ignorance), not to dogmatize upon the subject.—We shall first consider the *chemico-physical*, and then the *physiological* or *vital* properties of Fibrin.

25. The ultimate composition of Fibrin cannot be said with any degree of certainty to differ from that of Albumen, as will be seen from the following analytical results, which scarcely differ more from those already given for Albumen, than they differ from each other :—

| | Scherer. | Mulder. |
|---|---|---|
| Carbon | 53·6 | 52·7 |
| Hydrogen | 6·9 | 6·9 |
| Nitrogen | 15·7 | 15·4 |
| Oxygen, Sulphur, Phosphorus | 23·8 | 23·5 |
| Sulphur | | 1·2 |
| Phosphorus | | 0·3 |
| | 100·0 | 100·0 |

Most of the later elementary analyses of Fibrin support the view, that there is rather a larger quantity of oxygen contained in it, than in Albumen; but all these results are liable to fallacy, arising from the extreme difficulty of obtaining fibrin in a perfectly pure state;* and it would not be safe to rest much upon them. So long as Fibrin exists *in solution* (as in frog's blood, diluted with sugared water, and deprived of its corpuscles by filtration), it can scarcely be distinguished from Albumen by the effects of reagents upon it, nearly all substances which precipitate the one, precipitating the other also; ether, however, is an exception, for it causes fibrin to coagulate, whilst the albumen remains dissolved.—In its *spontaneously coagulated* state, Fibrin is a yellowish, opaque, fibrous mass, insoluble in water, alcohol, and ether; it possesses in this condition somewhat of the softness and elasticity which characterize the flesh of animals, and contains about three-fourths of its weight of water. By drying, this water may be expelled, and the fibrin becomes a hard and brittle substance; but, like flesh, it imbibes water again when moistened,

* See Lehmann, op. cit. p. 353.

and recovers its original softness and elasticity. Fibrin in this state is remarkably distinguished from coagulated Albumen, by its power of decomposing the peroxide of hydrogen, on which albumen has no effect. When Fibrin is treated with strong acetic acid, it imbibes the acid, and swells up into a transparent colourless jelly, which is soluble in hot water; this peculiar change showing a marked difference between fibrin and albumen, and indicating the relationship of the former to the substance of the gelatigenous tissues (§ 29). Again, when treated with water acidified with one-tenth part of hydrochloric acid, Fibrin swells up, and forms a gelatinous mass, returning to its original volume when more acid is added, and again swelling-up on the addition of water, without any notable proportion of it being dissolved; in this respect differing completely from the substance of Muscle, which is readily dissolved by dilute hydrochloric acid.* Coagulated fibrin, however, may be converted into a substance closely resembling albumen, by means which tend to destroy its peculiar molecular arrangement. This change happens, indeed, as a simple result of incipient decomposition; for under exposure to air, and with the presence of a sufficient amount of water, Fibrin at first dissolves away into a substance, which, like albumen, is coagulable by heat; during this process it attracts oxygen; and a continuance of the decomposition leads to the development of ammonia, carbonic acid, butyric acid, and sulphuretted hydrogen, and leaves a residue consisting principally of leucine and tyrosine (§ 19). It was long since pointed out by Denis,† that spontaneously-coagulated fibrin may also be reduced to a condition closely resembling that of albumen, by the action of nitrate of potash (this action, as is justly remarked by Lehmann, not being one of mere solution, but of transformation); and it has been since ascertained by Zimmermann, that various saline solutions will have the same effect upon fibrin digested in them.‡ Although there is much discrepancy in the evidence on this point, yet on the whole it seems that the fibrin of venous blood is thus taken up more readily than the fibrin of arterial blood, or than fibrin which has been exposed for some time to the air; and that exposure to the air has the effect of precipating the dissolved protein-compound in fine flocks; thus indicating that arterial fibrin is in a state of higher oxidation than venous fibrin, and is further removed from the state of albumen. The solution thus obtained coagulates in flakes at the temperature of about 162°; but it differs from an albuminous solution in being strongly precipitated by acetic acid; whilst, on the other hand, it is not coagulated by ether, as is true fibrin in solution.—When Fibrin is boiled, moreover, it is converted into a substance which can scarcely be distinguished chemically from coagulated albumen; and this operation prevents it from being converted into a soluble albumen-like substance by digestion in saline solutions. By continued boiling, however, with free exposure to the air, its character is further changed; and it is converted into the substance termed by Mulder *tritoxide of protein* (§ 29), which may also be obtained by treating albumen in the same manner.—Thus all the means which tend to bring back

* See Prof. Liebig's important Memoir on the distinction between the Fibrin of the Blood and that of Muscle, in the "Annalen der Chemie und Pharmacie," Band lxxiii.

† "Arch. gén. de Méd.," 3ième Sér. tom. i. p. 171.

‡ "Casper's Wochenschrift," No. 30, 1843.

Fibrin to the condition of a mere *chemical* compound, by destroying that peculiar molecular arrangement which its particles have acquired, tends to reproduce in it the properties of ordinary Albumen. Like Albumen, moreover, Fibrin is always in a state of intimate union with fatty substances; about $2\frac{1}{2}$ per cent of these being usually associated with it. Mineral substances, especially phosphate of lime, also present themselves in its ash; but usually in smaller proportion than in that of albumen.

26. The process of solidification of Fibrin, as ordinarily seen in the coagulation of the Blood when drawn from the vessels of the living body, is somewhat complicated by the presence of the corpuscles which are floating in the fibrinous fluid; and it can be better watched when these corpuscles have been separated from it, either by filtration, or by subsidence. Thus when the coagulation takes place at an unusually long interval after the blood has been drawn (as commonly happens in the case of inflammatory blood) the red corpuscles sink towards the bottom, in virtue of their higher specific gravity, and the fibrinous fluid is left free from them; and the same end may be obtained by covering the blood with a layer of oil, which, by excluding the atmosphere, retards its coagulation; or by treating it with dilute solutions of alkaline sulphates, nitrates, &c. which have a similar retarding effect. The first indication of the approaching change, as seen with the microscope in a thin film, consists in the appearance of minute molecular points, which are scattered over the field; and from these speedily arise fine thread-like prolongations, which radiate irregularly from them, crossing those that arise from other centres, and at last covering the whole field of view as with a delicate but somewhat irregular cobweb. This *fibrillation* seems to bear a certain analogy to crystallization, being the result of forces which tend to withdraw the solid particles from their state of solution in the liquid, and to bring them together in a certain definite mode of aggregation; and there are certain peculiarities in the process, which to some extent bear out this analogy. Thus, just as crystals will form around a nucleus of the same kind, from a solution which would not otherwise have deposited them, so will a fibrinous coagulum often separate from a serous fluid, and form around a piece of washed clot of blood, or of the buffy coat, or of muscle or some other animal tissue placed in it, although the fluid (such as that of hydrocele) would not have otherwise shown any disposition to coagulate.* It is to be remembered, however, that the processes of crystallization and fibrillation cannot be more closely likened, either in their conditions or in their results; for the latter occurs *only* in a substance which has been removed by *vital* action from the category of ordinary chemical compounds, and it produces a distinctly *organic* form; whilst in crystallization we have a typical example of the exertion of the purely *physical* forces, tending to produce a perfectly symmetrical and homogeneous body, whose shape is characteristically that of *inorganic* or mineral substances.

27. The degree of regularity with which this fibrillation takes place, and the completeness of the fibres which are formed by it, seem to depend

* Such appears to the Author to be the true view of the results of the interesting experiments of Prof. Buchanan of Glasgow; for an account of which see the "Proceedings of the Glasgow Philosophical Society" for 1845, and the "Medical Gazette" for 1836, pp. 52 and 90, and for 1845, p. 617, et seq.

especially upon two conditions,—1st, the degree of previous elaboration to which the fibrin has been subjected,—and 2nd, the properties of the surface on which it takes place. Thus we find the coagulum of some specimens of blood to be much firmer, and its fibrous structure to be more distinct, than that of others; the fibrillation of the fibrinous fluid of inflammatory blood is usually more complete than that of ordinary blood; and that of the fluid of plastic exudations, formerly known as 'coagulable lymph,' is still more distinct. But further, the fibrillation takes place far more perfectly when the fibrinous fluid is effused on a living surface, than when it is spread out over dead matter; and thus it happens that fibrinous effusions are much more completely converted into fibrous tissue *within* the living body, and in immediate contact with living tissue, than they ever are when removed from it. A marked difference may be observed in this respect, between the superficial and the central portions of a blood-clot which has been effused in the substance of the living solids; for it is always in the former, that the organizing process is most advanced, a firm and distinct fibrous membrane being often found on the exterior of such clots, whilst their interior is soft and amorphous.* Generally speaking, the fibrillation is more perfect, the more slowly it takes place; and the higher the previous vitalization of the fibrine, the longer is it before it changes its state. Thus the coagulation of sthenic inflammatory blood, which produces a clot of remarkable firmness, is much longer in taking place than the coagulation of ordinary blood; whilst the coagulation of the blood of cachectic subjects, which takes place very rapidly, is feeble and imperfect. The plastic effusions poured out from the blood in these two opposite conditions, partake of the character of the blood itself; those of the inflammatory blood of a previously healthy subject being converted into fibrous membranes of considerable firmness (Fig. 2), which are subsequently penetrated by blood-vessels, and become regularly organized tissues; whilst those proceeding from the blood of cachectic subjects frequently undergo a certain degree of organization with great rapidity, but do not go on to the same perfection, and speedily degenerate.†

FIG. 2.

Fibrous structure of inflammatory exudation from peritoneum.

28. One of the most remarkable examples of the consolidation of a fibrinous exudation into a regular fibrous tissue (which, however, never becomes vascular), is afforded by the membrane adherent to the interior of the egg-shell (membrana putaminis), and also by that which forms the basis of the egg-shell itself (Fig. 3). Between the two, there is no essen-

* See Dr. G. Burrows, in "Medical Gazette," 1835; and Mr. Prescott Hewett, in "Medico-Chirurg. Trans." 1845.

† See especially Mr. Dalrymple's Memoirs "On the rapid organization of Lymph in Cachexia," in the "Med. Chir. Trans." vol. xxiii.; and "On the early organization of coagula and mixed fibrinous effusions under certain conditions of the system," Op. cit. vol. xxvii.

tial difference; as may be seen by examining "an egg without shell," as it is commonly termed (or rather one in which the shell-membrane has not been consolidated by the deposition of calcareous matter); or by treating the egg-shell with dilute acid, so as to remove the particles of carbonate of lime, which are deposited in the interstices of the network. The place of the shell is then found to be occupied by a membrane of considerable firmness, closely resembling that which lines the shell and surrounds the albumen of the egg, but thicker and more spongy. After maceration for a few days, either of these membranes may be separated into a number of laminæ; each of which (if sufficiently thin) will show a beautiful arrangement of reticulated fibres. It is impossible to refuse to such a structure the designation of an *organized tissue*, although it contains no vessels, and must be formed by the simple consolidation of a fibrinous exudation, poured out from the lining membrane of the oviduct of the bird, so as to invest and inclose the albuminous exudations which have been previously poured out, layer by layer, around the yolk-bag. It is probably in the same manner, that the Chorion of the Mammiferous animal originates; since this is a new envelope, formed around the ovum, during its passage along the Fallopian tube. In the latter, for an ulterior purpose, vessels are afterwards developed, by extension from the contained ovum; and by the nutrition they supply, its size is increased, and changes take place in its texture. But in the egg-membrane of the Bird, there is no need of vessels; because no subsequent change in its texture is required, and its duration is sufficient for the purpose it has to answer.

FIG. 3

Fibrous membrane from the Egg-shell.

29. Thus, then, we are led to regard the fibrillation of Fibrin as a process quite different from the coagulation of Albumen or Casein; and to consider it as an expression or manifestation of the vital force with which the former has been endowed, during that *Assimilation* of the crude material furnished by the latter, which seems to be the first step in its conversion into living tissue. And this view is confirmed by many facts, which will be more appropriately stated when the Blood is under consideration (CHAP. IV.), and which show that the condition of the Fibrin in that fluid is intimately related to the vital powers of the system at large. When this fibrillation takes place out of the body, it may probably be regarded as the ultimate manifestation of the vitality of the Fibrin, which is expended in producing it; and thus it happens that the fibrinous coagulum passes into decomposition, without attaining any higher grade of development. But when it takes place in contact with a living surface, the exuded material, continuing to receive vital influence from this, and becoming penetrated by fresh blood conveyed in vessels that extend themselves into it, gradually passes into a state of more complete organization, and is at last developed into the condition of a living tissue. It is an obvious error, therefore, to speak of the act of coagulation as an indication of the death of the Fibrin, since it is only so when the isolation of the substance prevents its vital force, which has been thus expended, from being

renewed; whilst, on the other hand, when the coagulation takes place under more favourable circumstances, it is simply the transition-stage between the existence of the fibrin in the liquid state and its existence as a part of the solid fabric, and must thus be regarded as a stage in its progress towards complete organization.—We are scarcely warranted, however, in hence inferring that Fibrin is the *pabulum,* at the expense of which *all* the tissues are nourished. A very marked chemical line of distinction seems to separate the *simply fibrous* from the *proper cellular* tissues, for the former are *gelatinous* in their composition, whilst the latter are *albuminous;* and it has been recently asserted by Prof. Liebig, that fibrin, considered chemically, is in some respects intermediate between these two classes of compounds.* Further, it appears from Mr. Paget's observations on inflammatory effusions,† that the development of *cells* and the production of *fibres* do not take place with equal readiness in the same effusion; but that the condition of the plastic fluid which is favourable to the one, is unfavourable to the other. It may be surmised, then, that the peculiar vital powers with which the *fibrin* is endowed, give it a special tendency to development into tissues of the *fibro-gelatinous* type, which may thus be almost said to be *pre-formed* in the blood; whilst the tissues of the *cellulo-albuminous* type *develope themselves* at the expense of some other element of the blood, possibly the globulin of the floating corpuscles. But nothing certain can be stated on this subject.‡

30. The prolonged action of boiling water, with free access of air, upon Albumen and Fibrin, gives rise to changes in their condition, and probably also in their composition, which indicate a transition towards the gelatinous type. When Fibrin is thus treated, two new substances are produced, one of which is taken up by the water, whilst the other remains insoluble; the former is spoken of by Mulder as a *tritoxide of protein,* and the latter as a *binoxide;* but the propriety of these designations is extremely doubtful. When Albumen is thus treated, only the (so-called) tritoxide is produced; and the insoluble residue is still albumen. What-

* Prof. Liebig speaks of the fibrin of blood as "perhaps albumen half converted into gelatine." "Familiar Letters," p. 40.

† See his "Lectures on Inflammation," in the "Medical Gazette," 1850, vol. xlv. p. 1012.

‡ It might be thought that some notice is here required, of the hypothesis put forth by Dr. Zimmerman, and espoused by Mr. Simon and some other pathologists in this country, that the Fibrin of the blood is one of those elements of the circulating fluid "which have arisen in it from its own decay, or have reverted to it from the waste of the tissues," instead of being, as represented above, "that ingredient of the blood, which, in the ascending scale of development, stands next for appropriation into the living textures of the body, and which represents the ripeness and perfection and nutritiveness of the blood." (See Mr. Simon's "Lectures on General Pathology," p. 50). This doctrine seems to the Author to be completely opposed by the whole physiological history of Fibrin, and more particularly by the gradual development of this ingredient in chyle, during its onward progress towards the sanguiferous system; whilst, again, it seems to be entirely negatived by a comparison of the condition of fibrin with that of the *known* products of the disintegration of the tissues, such as urea or creatine, in which we see a marked tendency to the reproduction of purely physical and chemical conditions (and this pre-eminently in their crystalline aggregation), to the exclusion of those of vitality. We shall see that these last, although we know that they must be continually passing through the blood, are eliminated from it with such jealous care, that, in the healthy state, they scarcely accumulate in sufficient amount to be detectable; it is scarcely conceiveable, therefore, that fibrin, if a product of disintegration, on its way out of the system, should accumulate in the blood to the extent of between 2 and 3 parts in 1000.—For an examination of the objections brought by Mr. Simon against the commonly-received view, the reader is referred to the "Brit. and For. Med. Chir. Rev." vol. vii. p. 473.

ever may be the real composition of these substances, their presence in the living body, and their artificial production from the protein-compounds, give them an undubitable importance.—The *tritoxide of protein* is, like gelatin, readily soluble in water, and is insoluble in alcohol and ether; it is precipitated from its solution by dilute mineral acids, chlorine-water, tannic acid, corrosive sublimate, and most of the salts of the metallic oxides; but it is not thrown down by dilute acetic acid, by neutral alkaline salts, nor by that very delicate test for the ordinary protein-compounds (§ 18), ferrocyanide of potassium. When dried, it is easily pulverizable; but when moist, it is tough, viscid, and capable of being drawn out in threads; and when warmed, it has an odour resembling that of gelatin. It is probable that a small quantity of this substance always exists among the 'extractive matters' of the Blood; but it may be obtained in considerable amount from the 'buffy coat' of inflammatory blood; and when its presence was first detected there, it was mistaken for gelatin, so similar are its properties. According to Mulder, it is chemically identical with the substance termed *pyin*, which was discovered by Güterbock in pus; and it is a very significant fact, that the basis of false membranes, and that of the skin of the fœtus, both of them being fibrous tissues in an incipient grade of formation, have been considered to bear a closer resemblance to pyin than to any other organic compound. It may be anticipated, then, that more accurate investigations in regard to the composition and physiological relations of this substance, may help to bridge-over the hiatus which at present exists between the albuminous and gelatinous compounds.—The undissolved residue left when fibrin has been boiled for some time, to which the name of *binoxide of protein* has been given, is soluble in dilute acetic, hydrochloric, nitric and sulphuric acids, and also in potash and ammonia, and it is precipitated from its acid solutions by ferrocyanide of potassium and acetate of lead; in these respects, therefore, agreeing with the protein-compounds. This substance also seems to exist in the buffy coat of the blood, and perhaps too in healthy blood; but the chief interest attaching to it arises from the fact, that a substance apparently identical may be obtained from Hair, by dissolving this in potash, adding a little acetic acid to throw down the protein, and then adding a larger quantity of the acid, which throws down the binoxide of protein as a bright yellow precipitate.

31. Although differing considerably from the protein compounds in its chemical constitution, the *Hæmatin*, which forms the colouring portion of the contents of the red corpuscles of the blood, will be here most appropriately noticed; being obviously a derivative from albumen, and being not improbably in progress of preparation to bear a part in the composition of higher tissues. Hæmatin is so intimately united with the Globulin of the red corpuscles (§ 23), that the two substances can only be separated after their solidification; what is said of its properties, therefore, refers only to its coagulated state. It constitutes, when dried, a dark brown, slightly lustrous mass, which is devoid of taste and smell, and is insoluble in water, alcohol, and ether; it is readily dissolved, however, by weak alcohol to which sulphuric or hydrochloric acid has been added, and forms a brown solution, which, on saturation with an alkali, yields a blood-red colour. Water acidulated with the same acids, exerts no solvent power on hæmatin; but very dilute solutions of the caustic alkalies or

their carbonates, either in water or in alcohol, dissolve hæmatin in almost every proportion. In ultimate composition, Hæmatin departs widely from either the albuminous or the gelatinous type, and is remarkable for containing a considerable proportion of iron; as is seen by the following statement founded upon Mulder's analyses :—

| | |
|---|---|
| Carbon | 65·3 |
| Hydrogen | 5·4 |
| Nitrogen | 10·4 |
| Oxygen | 11·9 |
| Iron | 7·0 |
| | 100·0 |

Much controversy has taken place regarding the condition in which the Iron exists in Hæmatin; and the question cannot be regarded as yet satisfactorily determined. This much, however, is certain; that the red colour is not due, as has been commonly supposed, to the presence of iron; since it has been clearly shown by Scherer, Sanson, and Mulder, that the iron may be abstracted from this red pigment, by the agency of acids, without in the least degree affecting its colour.—Of the mode in which Hæmatin is generated, and of its office in the animal economy, we are at present completely ignorant. It would appear to be formed by the agency of the blood-cells, at the expense of the components of the fluid in which they float; and it is considered probable by Lehmann, that in this metamorphosis fatty matter takes an essential part. Hæmatin does not present itself normally anywhere else than in the red corpuscles; and although there appears some reason to believe that these are specially connected with the activity of the respiratory process (§ 147), yet no direct evidence has yet been obtained as to the mode in which they minister to it.* The colour of muscular tissue seems to be dependent, not merely upon the blood which circulates through it, but also upon the contents of its tubular fibres; so also does the hue of the vesicular element of nervous tissue depend partly upon the pigmentary matter contained within its cells. It does not seem, then, to be an unreasonable surmise, that the hæmatin of the blood-corpuscles is a substance which is being prepared by them for the nutrition of these tissues; and this idea is confirmed by the special relation which seems to exist, between the presence of a large proportion of corpuscles in the blood, and the nervo-muscular power of the animal (§ 147).—Nearly allied to hæmatin is a substance to which the term *Hæmatoidin* has been given, and which may be regarded with probability as hæmatin in a state of retrograde metamorphosis. This is found in sanguineous effusions, such as those in the substance of the brain or skin, or those produced by the bursting of the Graafian follicles for the extrusion of the ova; and it presents itself most characteristically in the form of rhombohedric crystals, of a yellowish-red or ruby colour, although it frequently occurs in the amorphous condition of granules and irregular masses. This substance has not yet been obtained in a state sufficiently pure, and in a quantity large enough, to admit of

* It may, however, be said with almost positive certainty, that the notion put forth by Prof. Liebig—that it is the *iron* of the blood-cells which serves as the carrier of oxygen from the lungs to the tissues (being then in the state of peroxide), and of carbonic acid from the tissues to the lungs (being then in the state of carbonate of the protoxide),—is not now held by any chemist of repute, and ought to be entirely abandoned.

its being subjected to a rigid examination; but it has been ascertained to be insoluble in alkalies, and to behave differently from hæmatin with other reagents. Hæmatoidin has been inferred by Virchow, from his recent investigations,* to be a compound of hæmatin and some protein-substance, the latter probably forming the crystalline, and the former the colouring portion of the compound; and this seems the more likely, since Reichert has found an albuminous substance, in the form of tetrahedral crystals, in extravasated blood. It seems probable, further, that hæmatoidin is a stage of transition between the blood-pigment and the colouring matters of the bile, namely, cholepyrrhin and bilifulvin (§ 70).

### 2. *Gelatinous Compounds.*

32. A large proportion, perhaps not less than half, of the tissues of the body of Man, as of that of the higher animals generally, is composed of a substance, which, when these tissues are acted-on by boiling water, dissolves in it, and forms a jelly on cooling. Some tissues dissolve readily in this manner, and leave scarcely any residue; whilst others require a longer coction, and a larger proportion of insoluble matter remains. The substance thus obtained from bones, cartilages, tendons, ligaments, skin, mucous and serous membranes, &c. is known under the generic appellation of *Gelatin;* there are, however, two forms of it, one of which is distinguished as *glutin* or gelatin-proper, whilst the other is known as *chondrin.* Although differing in their ultimate composition and in their behaviour with re-agents, these two substances agree in certain characteristic peculiarities, by which they are distinguished from the protein-compounds. These are, — their sparing solubility in cold water, the contact of which, however, makes them swell up and soften; their ready solubility in hot water, with the formation of a jelly as the solution cools, this being more or less stiff according to the source from which the Gelatin has been obtained, and the proportion of it which has been dissolved; and the readiness with which both forms are thrown down by tannic acid and chlorine-water, whilst they are unaffected by ferrocyanide of potassium.

33. *Glutin* is the form of gelatin which is yielded on boiling by the White Fibrous tissue wherever it occurs, and by the animal basis of Bone, which is nearly identical with this. It gelatinizes so strongly, that 1 part of it in 100 of water forms a consistent jelly on cooling. Its reaction with tannic acid is so distinct, that the white cheesy precipitate which this reagent forms, is visible in a solution of 1 part of glutin in 5000 of water. This, however, is the only acid which throws down glutin from its aqueous solution; and alkalies have no other effect, than that of precipitating a little bone-earth. Creosote gives the solution a milky turbidity; but the only earthy and metallic salts which precipitate it are corrosive sublimate, bichloride of platinum, and sulphate of binoxide of platinum. In this respect, as we shall presently see, glutin differs markedly from chondrin. If the solution of glutin in hot water be boiled for some time, it loses the property of gelatinizing, and at the same time phosphate of lime is separated from it (Liebig's "Familiar Letters," p. 387, note); and a similar effect is produced by repeatedly dissolving

* See "Ann. der Chem. und Pharm.," band lxxviii. p. 353.

glutin in hot water with exposure to air. Putrefaction takes place more readily in glutin than in fibrin under similar circumstances; and according to Gannal, the gelatigenous tissues are the first of the solid animal structures to become putrid.—Glutin does not seem to include phosphorus as one of its necessary components; and the quantity of sulphur which it contains (about 0·50 per cent, according to Prof. Liebig) is much smaller than that which enters into the composition of the Albuminous substances. But it appears to form definite chemical combinations with phosphate and carbonate of lime, since in the substance not merely of normal osseous tissue, but of the abnormal ossifications of fibrous membranes, &c. no such *heterogeneousness* is seen, as would be produced by a mere interstitial admixture of the organic and earthy matters. The latter are easily separated, however, by the action of dilute acids.—When Glutin is boiled for some time in caustic potash, it is decomposed, with escape of ammonia; and two new compounds, *leucine* and *glycine* are produced. The formation of the first of these is of peculiar interest; since, as the same substance is obtainable by the same agency from the protein-compounds (§ 19), a certain similarity in the arrangement of the ultimate elements of these two bodies is indicated, notwithstanding their differences in composition and characters. Glycine (or gelatin-sugar) is an organic base of much interest in its relations to certain excretory substances, as the hippuric acid of the urine, and the glycocholic acid of the bile (§§ 58, 68); it has a strong sweet taste, and is very soluble in water, from which it may be crystallized like ordinary sugar; and its composition is comparatively simple, its formula being 4 Carbon, 4 Hydrogen, 1 Nitrogen, 3 Oxygen.

34. The general properties of *Chondrin* are very similar to those of Glutin; but it is obtainable only from Cartilages, and this after very prolonged boiling; and it differs from glutin in being precipitated by certain reagents, which have no effect upon the latter. Thus, most acids throw down a precipitate from a solution of chondrin, though this may escape notice on account of the facility with which it redissolves in a slight excess of the acid; a considerable precipitate, however, is thrown down by acetic acid, which is not re-dissolved by any excess or even by concentrated acid. Chondrin is also precipitated by a number of metallic and other salts, which have no such effect on glutin; among the most important of these are alum, the sulphates of the protoxide and peroxide of iron, sulphate of copper, acetate of lead, and the nitrates of silver and of the suboxide of mercury.—The comparative elementary composition of these two substances is shown in the following table; from which it appears that, the proportions of carbon and hydrogen being nearly the same in both, glutin contains much more nitrogen and less oxygen than chondrin.

| | Glutin. | | Chondrin. | |
|---|---|---|---|---|
| | Mulder. | Scherer. | Mulder. | Scherer. |
| Carbon . . | 50·4 | 50·8 | 50·0 | 50·7 |
| Hydrogen . . | 6·7 | 7·1 | 6·6 | 6·9 |
| Nitrogen . . | 18·3 | 18·3 | 14·4 | 14·7 |
| Oxygen, Sulphur . . | 24·6 | 23·8 | 29·0 | 27·7 |
| | 100·0 | 100·0 | 100·0 | 100·0 |

35. It is remarkable that, notwithstanding the very large proportion of

the entire mass of the body, which is formed by the Gelatigenous tissues, no Gelatin should be detectable either in the Blood, or in any of the healthy fluids; and this fact seems to indicate that the transformation of protein-compounds into gelatin, which *must* take place wherever the food does not contain that substance (as in the case of herbivorous animals and of the embryo within the egg), is effected in the very act of their conversion into fibrous tissue,—a view which appears to derive probability from the various facts already stated respecting the properties of Fibrin (§§ 25, 27). If this be true, it seems highly improbable that the gelatigenous tissues are ever produced in any other way, or that gelatin employed as food can ever acquire even the low degree of organization which they exhibit; and reasons will be hereafter given for the belief, that this substance cannot be truly regarded as a histogenetic material, but must be looked upon merely as a pabulum for the combustive process (see CHAP. VII.).—Some Chemists, indeed, maintain, that Gelatin is rather a product of the operation practised to separate it, than a real constituent of the living solids; but this idea is inconsistent with several important facts. Thus, the gelatigenous tissues will exhibit, without any preparation, the best-marked of the chemical properties by which Gelatin is characterized,—that of forming an insoluble compound with tannic acid; and the tanno-gelatin, which may be obtained by precipitating gelatin from its solution, appears to be identical with that which results from the action of tannin on animal membrane, in every respect save the want of its organic structure. A similar precipitate is thrown down, as Dr. Alfred Taylor has recently shown, by adding tannic acid to the solution obtained by acting on Skin with acetic or oxalic acid. And further, the composition of gelatin, and that of the gelatigenous tissues (allowance being made for the presence of other ingredients in the latter), are found by ultimate analysis to be identical.—The fact appears to be, that there is somewhat of the same difference between gelatin, chemically considered, and the fibrous tissues, bone, &c. from which it is extracted, that exists between albumen and muscular fibre (§ 21); chemically they are identical, but the molecular arrangement of the particles has been altered by organization, so that the operation of solvents is required to bring back the organic compounds to their original structureless condition. And this view harmonizes well with the fact, that the tissues which are most readily dissolved by hot water, and on which cold water has the most action (such as those of the air-bladder of the fish), are those which have the *least definite* organic structure; whilst, on the other hand, those of which the fibrous structure is *most complete*, require the most prolonged action of hot water to gelatinize them. There is a difference, too, in the characters of the gelatin obtained from these different sources; for that which is so readily yielded by the fish's air-bladder, and is known as 'isinglass,' never forms a strong glue, even when quite dry; so also the gelatin of the skin of young animals, which forms 'size,' though setting more firmly than isinglass, cannot be advantageously employed by the carpenter; his hard 'glue' being all obtained from the skin, bones, &c. of adults. These differences have been imputed by Dr. Prout to diversities in the quantity of water held in combination by the gelatin.—The extreme difficulty which attends the first solution of Chondrin, cannot, however, be thus explained; and must be imputed to some peculiarity

in the molecular aggregation of the substance, which does not manifest itself in a fibrous arrangement.—It is interesting to remark that, of all the gelatigenous tissues, there is not one which can be said to have other than *mechanical* functions, such as that of binding parts together, resisting tension, or antagonizing pressure. On the other hand, all the proper *vital* functions of the body are performed by tissues whose composition is albuminous.

### 3. *Oleaginous Compounds.*

36. We now arrive at the *non-azotized* division of the organic compounds entering into the composition of the animal fabric; and the first group to be noticed, as connecting the histogenetic substances with the mere combustive materials, is that of the *Oleaginous* or *Fatty* matters. These are preeminently remarkable for the small amount of oxygen which enters into their composition, and for containing carbon and hydrogen in nearly equivalent proportions; they are soluble in ether and hot alcohol; but they are insoluble in cold alcohol and in water. Fatty substances are ranked as *saponifiable* or *non-saponifiable*, according as they are or are not decomposed by strong bases, such as alkalies or the oxide of lead. When this decomposition takes place, the fatty matter is separated into two constituents; an acid, which unites with the stronger base to form a soap or a plaster; and a weak base, which is set free. How far this acid and base have a separate existence previously to the act of saponification, or are formed in the process itself, cannot at present be positively stated. It is a remarkable fact, however, that the separation of the fatty acids from their base may be affected also by the agency of putrescent albuminous matters; and this has been shown by Lehmann to occur during the fermentation of milk.

37. The fatty substances which present themselves most largely in the Human body, are Margarin and Olein; the former of these being solid when separate, but being dissolved in the latter (which retains its fluidity when cooled down below 0° Fahr.) at the ordinary temperature of the body. In the fat of most other animals, the Margarin is replaced by Stearin; and these two substances, as will be presently shown, have very close chemical relations.—*Margarin* exists in small quantity, along with stearin, in most animal fats; and it is the principal solid constituent of the vegetable fats, with which, therefore, Human fat more closely corresponds than does that of most other animals. It is a white, solid, spermaceti-like substance, which melts at 118°, and which crystallizes from its solution in hot alcohol as a flocculent white powder, that is found by the microscope to consist of very delicate and often curved needles, often so grouped as to radiate from a central nucleus, an appearance not unfrequently seen within the cells of Adipose tissue.—*Stearin* is also a spermaceti-like substance; but its melting-point is higher, namely, 144°; and it separates on cooling from its solution in hot alcohol (which takes up less of it than of margarin) in snow-white glistening scales, which are either rhomboidal tablets, or short rhombic prisms.—*Olein* exists in small quantity in the solid fats, but constitutes the principal part of the fixed oils; and the tendency of these to solidification by cold depends upon the amount of stearin or margarin which they may contain. When separated from these, it is a simple colourless oil, which has a peculiar tendency to

become rancid on exposure to the air.—The following results of the ultimate analysis of the fat of different animals, by Chevreul, will show the close correspondence in their composition; whilst it also makes apparent the very large proportion of Carbon which they all contain.

| | Hog's Lard. | Mutton Fat. | Human Fat. |
|---|---|---|---|
| Carbon | 79·098 | 78·996 | 79·000 |
| Hydrogen | 11·146 | 11·700 | 11·416 |
| Oxygen | 9·756 | 9·304 | 9·584 |
| | 100·000 | 100·000 | 100·000 |

38. The saponification of these fatty substances gives rise to the production of the Margaric, Stearic, and Oleic acids, and of the base known as Glycerine.—*Margaric* acid is a solid white substance, destitute of smell or taste, which crystallizes from a hot alcoholic solution in groups of very delicate nacreous needles, that under the microscope appear interlaced like tufts of grass; it melts at the temperature of 133°; and when further heated, it decomposes and becomes inflammable. Its alcoholic solution has a slightly acid reaction with litmus-paper.—*Stearic* acid closely resembles the preceding; but it is less soluble in hot alcohol, so that when both are dissolved together, it is the first to crystallize as the alcohol cools, and its crystals have the form of elongated lozenge-shaped plates. Its melting point is 167°; and its alcoholic solution has a sufficiently powerful acid reaction to dissolve the alkaline carbonates.—*Oleic* acid, like olein, is liquid at ordinary temperatures, and is a limpid oily fluid, having neither taste nor smell, and exerting no action upon litmus. In this state, when freely exposed to the atmosphere, it absorbs twenty times its volume of oxygen, without giving off carbonic acid, and becomes changed into a thicker fluid which reddens litmus; so that oleic acid usually exhibits this reaction, unless special care have been taken to obtain it in a state of purity. When cooled down to about 43°, however, oleic acid solidifies into a hard white crystalline mass, which remains unaffected by exposure to the atmosphere. It is soluble in alcohol at ordinary temperatures; but crystallizes out of this solution in long needles, when it is exposed to extreme cold.—The following table of the atomic constitution of these acids, will assist in showing their mutual relations.

| | Stearic. | Margaric. | Oleic. |
|---|---|---|---|
| Carbon | 68 | 34 | 36 |
| Hydrogen | 66 | 33 | 33 |
| Oxygen | 5 | 3 | 3 |
| Water | 2 | 1 | 1 |

Thus it appears that Stearic acid is the equivalent of two proportionals of Margaric acid, *minus* 1 eq. of oxygen; and as it is easy to convert the former into the latter by dry distillation, there is every probability that stearic acid is formed in the living body at the expense of the margaric acid, which may be taken in as a constituent of vegetable food. Further, a relation between the Margaric and Oleic acids is indicated by the fact, that when the latter is exposed to the action of oxygen at an elevated temperature, it becomes converted into an acid whose composition is represented by the formula 34C, 33H, 5O; whilst the former, when treated with peroxide of lead so as to be made to undergo further oxidation, is converted into an acid whose composition is represented by the formula

34C, 33H, 4O + HO; so that these two compounds appear to present different grades of oxidation of one and the same radical.

39. The substance known as *Glycerine* is produced in the act of saponifying the ordinary fats of the body of man and of most other animals; and has been commonly regarded as the base with which the fatty acids are united to form them. It has not been found possible, however, to reproduce margarin, stearin, or olein, by combining their respective acids with glycerine; and there are moreover adequate reasons for considering, that the real base of the fats is a compound having the composition 3C, 2H, O, whilst glycerine is formed by 6C, 7H, 5O, and that two equivalents of the former are converted into one of the latter in the act of saponification, by the addition of 3 equiv. of water. To this hypothetical base, the name of *oxide of lipyl* has been applied.—Glycerine is a faintly yellow fluid, with an agreeable sweetish taste; it cannot be obtained in a solid form, but may be brought to the consistence of a thick syrup; it dissolves readily in water and alcohol, but not in ether; and it exerts no reaction on vegetable colours. It is remarkable for its solvent powers, which are scarcely inferior to those of water; and in particular for the large quantity of alkalies and metallic oxides which it will take up. When heated in the air, it becomes inflammable, and burns with a blue flame.

40. The saponifiable Fats ordinarily make up a considerable part of the substance of the Human body, and are found in large amount in its nutritious fluids. There can be no doubt that they are derived from the fatty components of the food, when these exist in sufficient amount; but there is also adequate evidence that fatty matters may be generated by the transformation of the Saccharine compounds. The experiments of Liebig, Dumas, Boussingault, Persoz, and others, have shown that animals fed upon an amylaceous diet form more fat than this contains;* but they have not made evident either the place in which that transformation takes place, nor the mode in which it is effected. The researches of M. Bernard, however, have thrown considerable light upon this subject; and have shown that the Liver is probably the organ by whose agency the production of fat is accomplished. For he has ascertained that the blood of the hepatic vein ordinarily contains more fat than that of the portal vein; and that the hepatic vein contains fat, when none can be found in the portal vein, the animal having been previously fed on substances containing no fatty matter. He has further ascertained that this production of fat is to a certain degree vicarious with that of sugar to be presently described (§ 46); the former being characteristic of herbivorous, and the latter of carnivorous animals; the former ceasing, when the latter is unusually excited by puncture of the medulla oblongata; and fat being deficient in the liver of diabetic patients, whilst conversely sugar is deficient in fatty liver.†—But there are certain phenomena attending the degeneration and decay of Albuminous substances, which seem to indicate that Fatty matter may be generated also by *their* metamor-

* See especially the Memoirs of the last-named experimenters in the "Ann. de Chim." Nouv. Sér. tom. xiv. p. 419.

† See the Reports of the Lectures delivered by M. Bernard before the College of France, in "L'Union Médicale" for 1850, Nos. 82, *et seq.*; and a very excellent digest of M. Bernard's recent contributions to Experimental Physiology, contained in the "American Journal of the American Sciences" for July and October, 1851.

phosis. This probability rests not only upon the fact, that acids of the butyric acid group have been actually generated during the decomposition of albumen (§ 18), but also upon the evidence afforded by that pathological change occurring in the living body, to which the name of "fatty degeneration" has been applied, and by that production of "adipocere" in dead bodies which sometimes takes place to a very remarkable extent. To the former class of phenomena, attention has been particularly directed by Prof. Rokitansky and by Mr. Paget; the former of whom* enumerates eleven classes of instances in which protein-compounds are replaced by fatty matter, in such conditions that it is hardly possible to assume anything but that the fat is one of the products of spontaneous transformation of the higher compound; whilst the latter † strengthens this view by various additional considerations. The substance termed *adipocere* is nothing else than a soap formed by the combination of fatty acids with an ammoniacal or calcareous base; and it may be generated in the course of even a few weeks by macerating a piece of muscle in water, as has been proved by various experimenters.‡—This conversion of protein-compounds into fatty matters, however, must always be looked-upon as a *pathological* change, when it occurs in the tissues; but its spontaneous occurrence must be admitted as valid evidence, that the fat which is generated in the liver may be formed out of the products of the disintegration of the albuminous tissues, or even by the metamorphosis of the albuminous elements of the food.§ In one of these two modes it seems evident that the liver-fat must be formed in Carnivorous animals; but in the Herbivora its materials will be more readily furnished by the saccharine alimentary matters.

41. The importance of these Fatty matters in the Animal economy, must not be estimated merely by the proportion of its fabric that is made up of *Adipose* tissue, the cells of which are filled with a mixture of Margarin (in man), or of Stearin (in most other animals), with Olein. For it is next to certain that the nutrition of *Nervous* tissue is effected in

* "Handbuch der Pathologischen Anatomie," band i. pp. 283–90.

† See Mr. Paget's "Lectures on Nutrition," Lect. v. in the "Medical Gazette" for 1847.

‡ It has been supposed by some, that the presence of adipocere is sufficiently accounted for by that of the fat previously contained in the muscular substance, and that the decomposition of the proper muscular tissue has no share in its formation, except as furnishing its base. This, however, is an untenable proposition. A body was exhumed at Bristol some years since, which had been buried during the Civil War, and which appeared externally in a state of remarkable preservation, the flesh retaining much of the plumpness of life; and as this was in a state of complete saponification, it is obvious that the amount of adipocere must have been far greater than the fat previously in the body would account for. And besides, the structural form of the muscular tissue may be clearly made out in adipocere produced by the action of water upon it. Further, it has been ascertained by Blondeau ("Compt. Rend." tom. xxv. p. 360), that the casein of cheese undergoes a gradual transformation into a saponifiable fat; and that the same change takes place in fibrin under similar circumstances.—For an excellent summary of the evidence upon this subject, with various pathological and experimental illustrations, see the Memoir of Dr. R. Quain on 'Fatty Diseases of the Heart,' in the "Medico-Chirurgical Transactions," vol. xxxiii.

§ Certain experiments of Boussingault upon ducks appear at first sight to favour the idea that fat may be formed from albuminous substances during the digestive process; but, as has been pointed out by Lehmann (op. cit. vol. i. p. 258) these results are by no means sufficient to prove the existence of so remarkable a transformation, since the fatty matters found within the intestinal canal, when the birds had been fed on albumen and casein containing little or no fat, may have been derived from the bile.

great degree at their expense, although the precise composition of that tissue, and its chemical relations to the histogenetic substances, have not yet been elucidated. And we shall find that their presence in the Chyle and Blood has probably a no less intimate relation to the general processes of Nutrition, than it has to the formation of the tissues of which it is the more especial pabulum. Further, a considerable proportion of the fatty matters introduced into the nutritious fluids of warm-blooded animals, never forms part of their tissues at all, but is at once removed by a process essentially resembling combustion, on which the maintenance of the heat of the body is dependent.—The amount of fatty matter in the *Chyle* depends in great part upon the nature of the food, being larger in proportion as the digested aliment has contained a greater abundance of it; and its presence is indicated by the milky opacity that distinguishes this fluid from Lymph, to which in other respects it bears a close resemblance. This milky opacity is not so much due to the presence of the larger oil-globules, which are distinctly recognizable as such with the aid of the microscope; as it is to the diffusion of the fatty matter through the whole liquid, in particles of such extreme minuteness that their diameter can be scarcely measured, forming what has been termed by Mr. Gulliver the "molecular base" of the chyle. The fatty matter of the Chyle is for the most part unsaponified, and corresponds in its composition to that of the ordinary salts of the oxide of lipyl.—The amount of fat contained in the *Blood* is more constant, being comparatively little dependent upon the supply directly furnished by the food; and here, therefore, we have an additional proof that the organism itself possesses the power of generating fat from other materials, so as to supply what may be deficient in the aliment. In its normal condition, the Blood contains from about 1·4 to 3·3 parts of fat in 1000; but this proportion may undergo a large temporary increase, by the admixture of chyle peculiarly rich in oily matters. Thus when blood is drawn within an hour or two after a meal including much fat, particularly if this had been preceded by a long fast, the admixture of chyle is indicated by the "milkiness" of the serum, which is found on examination to depend upon the presence of the "molecular base" of the chyle; and the total proportion of fatty matter in the blood then considerably exceeds the average. In a few hours more, however, the serum recovers its usual clearness, and the excess of fat in the blood disappears; owing, it may be reasonably surmised, to its consumption in the processes of nutrition and respiration. The saponifiable fatty matters proper to the blood exist in it (excepting in the case just stated) only in the saponified condition; this change being due to the influence of the fixed alkalies with which they there come into contact. As already mentioned, they seem to be united with the Fibrin of the blood with peculiar intimacy, and they constitute not less than 3 per cent. of its substance; more than 2 per cent. of fat may be obtained from the dried blood-corpuscles; whilst the dry solids of the serum do not contain above 1·8 per cent.—The quantity of fat in the *Lymph* is never large; and usually only traces of this substance are found.

42. Next to the nutrition of the adipose and nervous tissues, the most obvious purpose to which the Fatty matters of the chyle and blood are subservient, is the maintenance of Animal Heat. The conditions of this calorifying process will be more particularly considered hereafter

(CHAP. XIII.); and at present it will be sufficient to state, that it seems essentially to consist in the union of the carbon and hydrogen of fatty and other combustible matters, with oxygen introduced by the respiratory process; thus generating carbonic acid and water, which are set free through the same channel.—But there is strong reason to believe, that Fatty matter performs a most important part in the assimilation of even the albuminous constituents of the food, and in their conversion into plastic material in the first place, and subsequently into actual tissue. It has been shown by Lehmann and Elsasser, that the combination of fat with protein-compounds renders the latter much more easily reducible by the digestive process; and it has also been shown by Lehmann, that the presence of fat is necessary to enable albuminous matters to act as ferments; whence he comes to the conclusion, on chemical grounds only, that "fat is one of the most active agents in the metamorphosis of animal matter." This view derives support from a large number of facts with which the Physiologist and Pathologist are familiar. For, as was first specially noticed by Ascherson,* fat is always present in considerable amount in newly-forming organized fabrics; it being an universal constituent of the nuclei of cells, both in the Vegetable and Animal kingdoms, and being a large component of embryonic structures generally. Moreover, as just now pointed out, the fat of the blood is most intimately associated, and is combined in largest amount, with the most vitalized constituents of the blood, namely, the fibrin and the corpuscles; and plastic exudations from the blood contain much more true fat than the non-plastic, although the latter may contain a considerable amount of cholesterin. So, again, those cancerous growths whose increase is most remarkable for its rapidity, contain a large amount of fat. The remarkable power which cod-liver oil has been found to possess, of promoting the nutrient processes in individuals labouring under tuberculous cachexia, can scarcely be attributed to anything else than to its furnishing an abundant supply of fatty matters in a form that renders them peculiarly easy of assimilation. Taking all these facts into account, we seem justified in accepting the conclusion, that in the metamorphosis of the albuminous constituents of the food into the organized tissues, of which they are the proper pabulum, fat takes an essential part; and thus it comes to have a much higher place in the economy of the living system, than has usually been assigned to it.†

43. Of the non-saponifiable fats, or 'lipoids,' there are two which appear to be normal constituents of the blood; though it is doubtful whether they are ever employed in the formation of tissue, and whether they are not rather to be looked-on as excrementitious products, resulting

* See his Memoir 'Ueber die physiologische Bedeutung der Fettstoffe,' in "Müller's Archiv." 1840.

† It was first discovered by Ascherson, that when an oil-globule is surrounded by an albuminous solution, it becomes invested by a pellicle of coagulated albumen; and he went so far as to present this as the type of cell-formation in the living body. In this, however, he was undoubtedly in error; for the passive coagulated albuminous pellicle thus formed has nothing in common with the activity of a true cell; and it may be generated, moreover (as shown by Mulder), around other substances, gum arabic for instance.—In connection with this subject, the Memoir by Prof. Bennett on "the Structural Relation of Oil and Albumen in the Animal Economy," in the "Edinb. Monthly Journ. of Med. Sci." vol. viii. p. 566, and his work on Cod-liver Oil, may be advantageously referred to.

from the disintegration of the living structure.—*Cholesterin* (or biliary fat), the most important of these, is a hard spermaceti-like substance, which separates from its solutions in nacreous scales that are found under the microscope to have the form of rhombic tablets; it is quite insoluble in water, but is soluble in ether, and also in boiling alcohol, from which, however, the greater part separates in cooling; it is also slightly soluble in soap-water, and more freely in the fatty oils and in taurocholic acid. It does not melt until heated to 298°, and it solidifies again and becomes perfectly crystalline at 275°. It is not decomposed by concentrated alkalies, even when the mixture is submitted to prolonged heat. Its composition is represented by the formula 37 C, 32 H, O; but its combining equivalent is as yet uncertain. Cholesterin is constantly present in the blood, to the amount of from ·025 to ·2 parts in 1000 (that is, from $\frac{1}{40}$th to $\frac{1}{5}$th of one-thousandth part of the whole mass); and its quantity seems to be augmented in old age, and in many acute diseases, as also in icterus. It is also stated to be a constituent of the nervous tissue, having been extracted from the brain by Couerbe and other experimenters; but it may be doubted whether it is not rather a product of the disintegration of nerve-substance, which is destined to be taken back into the blood for elimination by the excretory apparatus, like the kreatine which may be extracted from the juice of flesh (§ 60), or the urea which is obtainable from the vitreous humour of the eye (§ 53), both being undoubtedly excrementitious matters. For Cholesterine is a characteristic component of the biliary excretion, and is closely related to its peculiar acids;* so that it can scarcely be looked upon in any other light than as an excrementitious product, the highest function of which is to assist in the support of the calorifying process. It is frequently separated from the blood as a morbid product; thus it is often present in considerable quantity in dropsical fluids, and particularly in the contents of cysts; and may be deposited in the solid form in degenerated structures, tubercular concretions, &c.—Of the other non-saponifiable fat, termed *Serolin,* much less is known. It is obtained from the serum of blood, after the removal of the other fats; and seems to differ from cholesterin chiefly in having a lower melting point, 97°, and in separating from its alcoholic solution in nacreous glistening flocculi.

44. It has been supposed that the substance of the Brain contains fatty acids of a peculiar character, to which the terms *Cerebric* and *Oleo-phosphoric* have been given by Fremy. Both of these have been said to contain a large quantity of phosphorus, and the former to present the additional anomaly of a fatty acid containing nitrogen. It appears probable, however, that in the analysis of Nervous tissue which gave the latter of these results, due care was not taken to separate its fatty and its albuminous constituents; and that the supposed Cerebric acid has no real existence, being merely an admixture of albumen with an ordinary fatty acid.† Still it appears that the fats of the brain contain phosphorus in some peculiar state of combination, and similar "phosphorized fats"

* By the action of oxidizing agents upon Cholesterine, a peculiar acid, cholesteric acid, is obtained; and the same acid (as shown by Schlieper) may be obtained in the same way from the resinous acids of the bile, and from no other organic substance whatever. (See Liebig's "Familiar Letters," p. 440, note.)

† Liebig's "Animal Chemistry," 3rd Edit., p. 257.

are found in the blood; and the belief formerly expressed by Berzelius, that the phosphorized fats of the blood are chiefly contained within the red corpuscles, has been recently confirmed by the analyses of Lehmann, who has found in the red corpuscles of arterial blood 1·8 per cent., in those of venous blood no less than 3·6 per cent. of fat extractible by ether, which, when incinerated, yielded not less than 22 per cent of ash, chiefly consisting of acid phosphate of lime. — In what state this phosphorus exists, however, is as yet uncertain. It will be remembered that Prof. Liebig has lately affirmed very decidedly, that phosphorus does not occur, either in the nervous tissue or in any organic compound, except in the condition of phosphoric acid.—It remains to be seen, therefore, how far the fatty matters of the Nervous tissue are really peculiar to it, and whether, if they are different from the ordinary fats, the latter may be metamorphosed into them.

### 4. *Saccharine Compounds.*

45. Of the organic components of the human body, it now only remains for us to consider those of the *Saccharine* group, whose presence in the nutritious fluids, so far as at present known, serves no higher purpose than that of supplying material for the calorifying process, unless they can be indirectly made available, by undergoing conversion into fat, as materials for the generation of tissue.—The form of Sugar which appears to be normally present (usually, at least, if not constantly) in the Blood, is that known as *Glucose*, or "grape-sugar," which is the saccharine compound that is most commonly present in fruits, and that results from the transformation of starch by the action of acids, ferments, &c. This substance differs from cane-sugar both in composition and properties; for whilst the formula of crystallized cane-sugar is 12 C, 11 H, 11 O (which is considered as resulting from the combination of 12 C, 9 H, 9 O, the equivalent of anhydrous sugar, with 2 HO), that of crystallized glucose is 12 C, 14 H, 14 O, this also containing 2 equivalents of HO in combination with the sugar itself. Glucose is much less sweet than cane-sugar, is only half as soluble in water, and is much less disposed either to crystallize, or to enter into combination with oxide of lead and other substances. It has less, in fact, of those peculiar properties which so remarkably assimilate cane-sugar to inorganic compounds. We accordingly find that the relations of the two sugars to the animal economy are very different. Cane-sugar, when injected in any considerable amount into the general current of the circulation, is neither assimilated nor removed by the combustive process; but, like soluble salts thus introduced, is speedily removed by the kidney, being discovered in the urine.* On the other hand, a much larger quantity of grape-sugar may be injected into the general circulation, without any trace of it becoming detectable in the urine;† hence

* This has been shown by various experimenters, among whom Dr. Percy ("Medical Gazette," vol. xxxii.), Prof. Lehmann ("Physiological Chemistry," vol. i. p. 293), and Dr. Cl. Bernard ("Compt. Rend." tom. xxii. pp. 534–537), may be particularly mentioned.

† The following are given by Magendie as the proportions in which different sugars require to be injected into the jugular, in order that they should be discoverable in the urine.

| | |
|---|---|
| Cane-sugar . . . | 1 |
| Mannite . . . . | 1 |

it is obvious that this is applicable to some purpose within the system, and does not require to be cast out as a foreign substance. The presence of Glucose in the Chyle and Blood appears to depend upon the presence of either starch or sugar in the food. The transformation of starch into glucose is effected, as will hereafter be seen, during the passage of the alimentary matter along nearly the whole length of the canal; this conversion being begun by the saliva, and continued by the pancreatic and other secretions which are poured into the intestinal tube. That the glucose thus formed is partly taken up by the lacteals, appears from the experiments of Trommer and Lehmann;* but that it is also more directly absorbed into the blood-vessels, like other soluble matters, by simple endosmose, has been determined by M. Cl. Bernard,† who has always met with distinct traces of cane-sugar in the blood of the vena portæ of animals that had been fed upon it; and there appears to be a special provision in the liver for the conversion of the sugar thus absorbed, into the form in which its presence in the blood can be best tolerated, until it is eliminated by the respiratory process. For it appears from the experiments of M. Bernard (loc. cit.), that although cane-sugar is rapidly eliminated by the kidneys when it is injected into the *general* circulation, it may be injected in considerable amount into the *portal* system, without producing any such effect. When large quantities of saccharine or of amylaceous matters have been employed as food, the general mass of the blood is found to contain an appreciable portion of sugar, as has been shown some time time since by Prof. R. Thompson,‡ and M. Magendie.§ But it has been recently shown by M. Bernard, that a sugar nearly allied to glucose is a *constant* constituent of the blood drawn from the hepatic vein, ascending cava, right auricle, and pulmonary artery of all animals, whether they have been fed upon amylaceous or saccharine substances, or upon food entirely destitute of these principles;—a fact of the highest interest, of which the explanation will presently appear.

46. From the readiness with which Glucose undergoes transformation into lactic acid, in the presence of azotized compounds, there can be little doubt that this change is continually taking place in the living body; and it is probably in the form of lactic acid, that glucose is rendered subservient to the maintenance of animal heat by the combustive process. Such, therefore, we may consider to be the usual destination of the Saccharine compounds introduced as food. But, as already mentioned, there is ample evidence that, when there is a deficiency of fatty matters in the food, these may be formed by a metamorphosis of its saccharine constituents; and with this change, there is a strong probability that the Liver is chiefly concerned. But further, evidence has been recently obtained, that this important organ can actually *generate* Sugar from

| | |
|---|---|
| Sugar of Milk . . . | 5 |
| Glucose . . . . | 50 |
| Sugar of the Liver . . | 240 |

Thus we see that 50 times as much of glucose as of cane-sugar, and nearly 5 times as much of liver-sugar as of glucose, is required to produce this effect. (See "L'Union Médicale," 1849, Nos. 72, 75, 79).

* "Physiological Chemistry," vol. i. p. 289.

† "Gazette Médicale, 1850, No. 5.

‡ "Philos. Magaz." April and May, 1845, and "Medical Gazette," Oct. 10, 1845.

§ "Compt. Rend." tom. xxx. pp. 191, 192.

other than amylaceous compounds; for it has been ascertained by M. Bernard, that the substance of the liver contains sugar, even in animals that have been fed for some time on animal food alone (a discovery which has been verified in the Giessen Laboratory),—that the blood of the hepatic vein of such animals contains sugar, although none is to be found in that of the vena portæ,—and that sugar is contained in the liver of embryoes, both of mammals and oviparous animals. In the case of a healthy adult who was guillotined while fasting, it was calculated from the analysis of a portion of the liver, that the whole mass of it must have contained 360 grains of sugar. In Herbivorous animals, whose food contains a large supply of amylaceous and saccharine matter, it appears that the liver does not thus furnish any large quantity of this sugar; whilst on the other hand, a portion of the saccharine constituents of the portal blood seems to be converted into fatty matter in its passage through the liver. But in Carnivorous animals, which have already a supply of fat in their food, but no sugar, the transforming process would seem to be of a different kind, sugar being generated *de novo,* although from what element of the blood it is produced, has not yet been clearly determined. There seems a strong probability, however, that the production of sugar takes place at the expense of protein-compounds; and that it is the chief means by which the products of the disintegration of muscular and other albuminous tissues are made available for the maintenance of animal heat by the combustive process; and this view derives confirmation from the fact, that a new form of Sugar, termed *Inosite,* whose formula is 12 C, 16 H, 16 O, has been recently discovered by Scherer in the 'juice of flesh,' where its presence is almost undoubtedly to be attributed to the disintegration of muscular tissue.* (See also § 91, VI.) Of the characters of the sugar thus produced in the liver, little is yet definitely known; but it would appear far to surpass even glucose in the readiness with which it is carried off by the respiratory process; for according to the statement of M. Bernard, as much as 12 grammes may be injected into the blood with no more effect upon the urine than is produced by 2·5 grammes of glucose, or by ·05 of cane-sugar.†

47. This metamorphic action of the liver would seem to be influenced by conditions of the nervous system; for when the upper part of the medulla oblongata, near the origin of the pneumogastric nerve,‡ is

* "Ann. der Chem. und Pharm.," band lxxiii. p. 322.

† It is considered by M. Bernard, that *diabetic* sugar rather corresponds to this "sugar of the liver," than it does to glucose. He found no less than 833 grains of sugar in the liver of a diabetic subject; and he remarks that the liver is generally hypertrophied in this disease. Hence he looks to the liver as its primary seat; and imputes the glycosuria to an excessive production of sugar in the liver, which would seem then to exercise its metamorphic power upon the azotized constituents of the blood, and thus to destroy the material for the nutritive processes,—an idea that corresponds well with the phenomena of the disease, which indicate an impoverishment of the nutritive fluid, the solids of the body exhibiting a rapid waste, notwithstanding that there may be an extraordinary appetite, and a very large amount of azotized nutriment may be taken. Moreover, it would seem from Dr. Prout's observations, as if the presence of a small quantity of saccharine matter in the food tended to promote this metamorphosis in its other constituents; the eating of a single pear having been observed by him to neutralize all the benefit which had been obtained by an abstinence from saccharine and amylaceous matters, prolonged through several months.

‡ The part of which the injury is most effectual in producing this result, is that which lies in the groove between the corpora restiformia and corpora olivaria, and over the adjoining part of the latter.

irritated by puncture or by a slight galvanic shock, the production of sugar in the liver takes place to so great an extent, that a portion of this substance finds its way into the urine, and a temporary artificial diabetes is speedily established. This effect so speedily ensues, that sugar has been detected in the general mass of the blood, and in every secretion formed from it, except the saliva (into which he never found it enter) within twenty minutes after the operation. It is even possible, according to M. Bernard, to predict the amount of sugar that will be secreted, according to the depth of the incision. On the other hand, if the injury thus done be too great, or if a violent electric shock be transmitted through the medulla oblongata, or any other severe lesion be inflicted on the nervous system, the production of sugar is suspended; and it appears that the same suspension may occur as a result of diseases which produce a diminution of nervous power. Division of the pneumogastric nerves usually prevents the irritation of the medulla oblongata from exerting its usual effect, and even checks the production of sugar when it has already appeared in the urine; but this result is by no means constant.—The duration of the presence of sugar in the urine after the operation is variable, according to the animal experimented on and the method employed; in general it lasts forty-eight hours in the rabbit, and four days in the dog; but in one dog it continued for as much as seven days. The animals are extremely restless during this period; the respiratory movements are hurried; the arterial blood presents almost a venous tint; the quantity of carbonic acid given off is augmented; nevertheless the temperature of the body is diminished several degrees.*

48. In close relation with the Sugars, both chemically and physiologically, stands *Lactic Acid*, the presence of which, as a normal element of the blood, and as performing very important functions in the economy, may now be regarded as well established; and it will be conveniently considered here, although it might be in some respects more appropriately placed in the category of excrementitious matters.—This substance, in its most concentrated state, is a colourless, inodorous, thick, syrupy fluid, which cannot be solidified by the most intense cold, dissolves readily in water, alcohol, and ether, has a strongly acid taste and reaction, and dis-

* This last fact appears at first sight to stand in marked opposition to the chemical theory of Animal Heat; but the Author would suggest that the following may be its explanation.—The production of heat being dependent upon the combustion (or union with oxygen), not merely of carbon, but of hydrogen, and the amount of heat disengaged by the combustion of hydrogen being much greater than that given off by the combustion of its equivalent of carbon, we might expect that the conversion of a fatty substance, which is almost entirely composed of hydrogen and carbon, into water and carbonic acid, shall give off a far larger amount of heat, than the combustion of a farinaceous or saccharine substance, in which there is only carbon to be burned off, the hydrogen being already united with oxygen in the proportion to form water. Experience shows that such is the case; for in the Arctic regions, ordinary bread is found to be very inefficient for the maintenance of animal heat, although an ample supply of oleaginous matters is completely effectual for this purpose; and, as Sir John Richardson has informed the Author, it has been recently found by the Hudson's Bay traders, that *maize* bread, which contains a considerable proportion of oil, is a most supporting food. Consequently, when the production of *fat* by the liver is suspended, and the production of *sugar* takes its place, the amount of heat generated by the consumption of even an augmented quantity of the latter, will not be equal to that resulting from the combustion of the former; for only carbon will be burned-off in the one case, whilst both carbon and hydrogen were consumed in the other.—The above account of the researches of M. Bernard, is derived from the sources already referred to (§ 40, *note*).

places not merely volatile acids, but even many of the stronger mineral acids, from their salts. With bases it generally forms neutral salts, all of which are soluble in water; but the alkaline lactates, and some others, cannot be made to crystallize; being only brought, by the greatest concentration, to the condition of syrupy fluids. The composition of this acid is considered to be 6 C, 5 H, 5 O; and it thus bears a close relation to that of Sugar, being exactly half one equiv. of anhydrous Sugar + one equiv. of Water. It is, in fact, from sugar or starch that it is most directly produced; being the result of a new arrangement of the atoms of these substances under the influence of an azotized ferment, as when milk is turned sour by the action of its casein upon its sugar. But an acid may be extracted from the 'juice of flesh,' which, whilst apparently identical in composition and in most essential properties with that obtained from the fermentation of sugar, differs from it in certain of the properties of the salts which it forms with bases; and the acid of the juice of flesh has been recently distinguished as *a* lactic acid, whilst that obtained in the usual way (with which the acid of the gastric fluid corresponds) is designated as *b* lactic acid. This distinction will be found to be of much importance, when we examine into the sources of lactic acid in the animal economy.—Much discussion has taken place at different times with regard to the existence of lactic acid in various parts of the animal body, chiefly in consequence of the extreme difficulty of determining its presence by ordinary chemical tests; the production of some of its crystalline salts, and the accurate measurement of the angles of these, being the only method on which reliance can be placed. The following, according to Lehmann, may be regarded as well-established facts, free from the errors of the earlier analyses.

49. Lactic acid is a constant constituent of the *gastric juice;* and as this is true of carnivorous as well as of herbivorous animals, it cannot be looked on in any other light than as a secretion from the blood. It is also found in the contents of the *small intestines,* which, notwithstanding the neutralising power of the bile, usually exhibit an acid reaction; but although its presence there may be attributed to the admixture of the gastric solvent, yet, as it is found in much larger amount in the small intestines of herbivorous than in those of carnivorous animals, and as its proportion is increased in the former by the ingestion of farinaceous food, the excess would seem to be due to the direct transformation of amylaceous matters in the alimentary canal. The acid reaction of the mucus which lines the intestinal tube has been found to be due to lactic acid; as is also that which often presents itself in the contents of the large intestine, especially when vegetable food has been ingested. Distinct evidence has been obtained of the presence of lactic acid in the *chyle* of herbivorous animals, in which it is obviously derived from the food; on the other hand, there are indications of its existence in the *lymph,* where its presence must be rather attributed to its production in the muscular substance. It seems impossible to demonstrate the existence of lactic acid in healthy *blood,* by direct experiment; but, as Lehmann remarks, "the simplest induction proves that it must be present there, even if it only remains for a very short period;" since in no other way can it be understood how the lactic acid introduced by the chyle, or generated in the muscular substance, can find its way into the gastric, urinary, cutaneous,

or other secretions. The fact appears to be, that in the healthy state of the system, lactic acid is decomposed by the respiratory process, or is eliminated from the blood by the secretory operations, as fast as it finds its way into the circulation; and thus, as in the case of urea, it never accumulates in the blood to such a degree as to make its presence evident, unless it be either introduced in undue proportion, or its elimination be checked. It seems probable that when the blood presents an acid reaction, as happens in some diseases, this is to be attributed to an excess of lactic acid; since this substance, although not distinctly detected in such blood, has been clearly made out in the fluids exuded from it. The rapidity with which lactic acid is decomposed by the respiratory process (carbonic acid being left, in combination with the bases), may be judged of by the fact, that within from five to thirteen minutes after considerable quantities of the alkaline lactates have been introduced into the stomach, or have been injected into the current of the circulation, the urine is found to be rendered alkaline by the presence of their carbonates.—The existence of free lactic acid in the *juice of flesh*, as long ago asserted by Berzelius, may now be considered as a certainty; and it is probable that, as further maintained by Berzelius, the amount of free lactic acid in a muscle is proportioned to the degree in which it had been previously exercised. Now, that this lactic acid cannot have been generated by the direct transformation of the elements of food, and merely attracted from the blood by the muscular substance, but is one of the products of the direct transformation of that substance consequent upon the exertion of its vital powers, appears from this, that it is found in the muscles of purely carnivorous animals in no smaller amount than in those of the animals that have consumed amylaceous or saccharine matters as food; and although it has not yet been produced artificially, either by fermentation or otherwise, from any nitrogenous animal matter, yet, as is pointed out by Lehmann, there are strong indications that such a conversion is by no means hypothetical; and all that has been said of the generation of sugar in the body (§ 46), of course applies equally to lactic acid. —The occasional presence of lactic acid in the *urine*, appears to have been fully proved by the researches of Lehmann; who has shown that although it cannot be considered as a normal constituent of that excretion, it is liable to appear there, whenever the quantity introduced into the blood in a given time, whether by the transformation of the amylaceous and saccharine constituents of the food, or by the metamorphosis of muscular tissue, is greater than the respiratory process can carry off; and thus it may be habitually present in the urine of individuals whose respiration is obstructed, notwithstanding that no actual excess of it has been generated within their bodies.—Lactic acid seems also to be occasionally present in the *sweat* (which owes its sour smell, however, to acetic acid); and its presence has been suspected also in the *bile*, though with respect to this it would not be safe to make a positive statement.

50. On the whole, then, it may be positively affirmed, that Lactic acid is a normal constituent of the Human body, and that it is to be looked-on under two aspects, both as to its origin and its destination. Its *origin* may be attributed,—1st, to the direct transformation of the amylaceous and saccharine constituents of the food,—and 2nd, to the metamorphosis of muscular and (probably) other azotized tissues. On the other hand, its

*destination* may be considered as being,—1st, to supply a pabulum for the combustive process, and thus to contribute in maintaining the heat of the body,—and 2nd, to take part in the reduction of the albuminous and other constituents of food in the stomach, either by itself acting as the solvent, or by decomposing the chlorides of calcium or sodium contained in the gastric fluid, and by thus setting-free hydrochloric acid. Its presence in the urinary secretion may be regarded as exceptional; the kidneys affording (so to speak) a safety-valve, whereby the accumulation of lactic acid in the blood is prevented.

### 5. *Excrementitious Substances.*

51. Although it might seem more correct to proceed, in the next place, to speak of the Mineral or Inorganic constituents of the Human body, yet it will better serve the purpose of illustrating the chemical metamorphoses which take place in the economy, if we next direct our attention to those Organic compounds, which may be regarded as the products of the disintegration of the tissues, or of the decomposition of superfluous alimentary matter, and which, wherever they are found within the living body, may be considered as on their way to be eliminated from it by the action of the excretory organs.—Of these excrementitious matters it may be stated generally, that although their composition is such as (with very few exceptions) the Chemist is unable to imitate by the artificial union of their components, yet it is far simpler than that of the Histogenetic substances; the number of the combining equivalents of their elements being smaller, and the mode in which they are united (as indicated by the decompositions of which these compounds are susceptible) being usually much more apparent. Moreover, several of them are remarkable for their capability of assuming a *crystalline* form; which, as long since pointed out by Dr. Prout, is peculiarly indicative of their incapacity for serving as materials for the construction of living tissues. And of all of them it may be said, that their accumulation in the Blood is extremely deleterious; so that, if they should be generated faster than the excretory organs can remove them, a serious derangement of the vital economy is produced. These peculiarities separate the proper excrementitious substances from all those which are introduced into the body as food, and which serve either for the genesis of tissue, or for the supply of the combustive process; but, as already remarked, the two groups are connected by intermediate links,—cholesterine, though a normal element of the blood, being a component of the biliary excretion,—whilst lactic acid, though a most important ingredient in the gastric juice, is an essentially excrementitious product of the metamorphosis of the saccharine compounds, whose constant and complete elimination from the blood seems to be most carefully provided for.—Like the histogenetic substances, the proper Excrementitious matters may be divided into two principal groups, in one of which *nitrogen* is the predominating and characteristic ingredient, whilst in the other we find *carbo-hydrogen* in excess; and these two groups form the chief components of the Urinary and the Biliary excretions respectively.

52. Of the first of these groups, the substance of by far the most importance in the Human body, is *Urea;* and this, although not possessing an alkaline reaction, is regarded as *basic,* since it has the

power of forming saline compounds with acids. Urea is obtained from the fluids containing it, in a crystalline form: but the shape of its crystals varies according as it separates rapidly or gradually; these being white, silky, glistening needles in the former case; and flat, colourless, four-sided prisms, terminated by one or two oblique surfaces, in the latter. Urea is devoid of smell, has a saltish cooling taste, and is unaffected by exposure to the atmosphere. It dissolves readily in its weight of cold water, and in hot water in every proportion; it is also soluble in 4 or 5 parts of cold, and in 2 parts of warm alcohol; and it is not precipitated from its solutions by metallic salts, tannic acid, or any other reagent. It has been stated to combine as a base with a considerable number of acids; but the only salts which it is certainly known to form, are the nitrate, oxalate, and hydrochlorate; and it is by the use of either nitric or oxalic acid, that urea is most readily obtained from its solutions, since the salts which it forms with them are far less soluble in water than is urea itself. Urea unites also, however, with many salts, some of which hold it in such firm combination, that it cannot be thus separated from them.—The composition of Urea is extremely simple in comparison with that of the azotized histogenetic substances, its formula being 2 Carbon, 4 Hydrogen, 2 Nitrogen, and 2 Oxygen; but Chemists are not yet agreed upon the mode in which these atoms are united. The number of the combining equivalents of the respective elements is the same as that which exists in the Cyanate of Ammonia; and it was long since ascertained by Wohler, that this salt may be converted into (basic) urea by the re-arrangement of its atoms, without any alteration in its ultimate composition. This artificial production of urea may be considered as one of the most interesting discoveries ever made in organic chemistry. When organic matters, either putrefying or capable of undergoing putrefaction, are mixed with an aqueous solution of Urea, the latter is soon converted, with the addition of two equivalents of water, into Carbonic acid and Ammonia; thus restoring to the atmosphere, in their original state of combination, the compounds at whose expense the Plant first generated the organic constituents of the Animal body. This change takes place in the Urine very soon after its expulsion from the body; the mucus of the bladder acting as the ferment required.*

53. That Urea is to be regarded as one of the most important products of the disintegration of the azotized tissues of the body, cannot now be doubted for a moment. It may be produced by the decomposition of various nitrogenous substances, both natural and artificial; and it is a fact of the greatest physiological interest (as will be presently apparent), that it may be obtained from *creatine* by the action of baryta-water or alkalies. In inquiring into the precise mode of its production, we must trace it backwards (so to speak) from the Urine, of which in Man it is the characteristic ingredient.—There is now abundant evidence, that urea is not generated (as formerly supposed) in the act of secretion, but that it exists pre-formed in the blood; for not only does it accumulate largely in the circulating fluid, when its elimination by the normal outlet is checked, but it presents itself, though in extremely small amount, in healthy

* See MM. Dumas and Boussingault "On the Chemical and Physiological Balance of Organic Nature," 3rd edit. (transl.), p. 41; and the Author's "Principles of Physiology, General and Comparative," p. 186.

blood, as has been determined by Strahl and Lieberkühn, Garrod, and (still more decisively) by Lehmann. That its proportion in the circulating fluid never arises to an amount that would render it easily detectable, notwithstanding that it is continually either being generated within the vessels, or being absorbed into them from without, is readily accounted for by the avidity (so to speak) with which the kidney seizes upon even the smallest proportion of this substance, and eliminates it from the nutritive fluid. The purpose with which this organ has been enabled thus to act, becomes obvious enough when it is remembered that Urea is a substance whose accumulation in the blood is most pernicious; as is seen in various forms of disease, of which the most severe symptoms, and not unfrequently the fatal termination itself, are directly attributable to this mode of poisoning. Moreover, it has been shown by the calculations of Lehmann, that it would require the whole urea generated in the system to accumulate in the blood for at least an hour (so as to impregnate it with 1-24th part of the total quantity passed in one day) before it would amount to such a per-centage as can be certainly detected in that fluid. Even if it could never be recognized in healthy blood, therefore, no argument would be thence furnished against the doctrine that it is present as such in the blood before it passes to the kidneys. This doctrine is confirmed by the fact, that Urea may be discovered in various fluids separated from the blood; and this not only when the normal elimination is checked, but also in the usual state of health. Thus it has been found by Millon and Wohler in the vitreous and aqueous humours of the eye, by Rees in milk and liquor amnii, and by Landerer in the sweat; and when the renal arteries have been tied, or the kidneys have been removed, or their secreting action has been interfered with by injury to their nerves or by disease, Urea has been detected in almost every secretion and fluid exudation that has been drawn or poured forth from the circulating current.—The question now arises, whether the Urea thus contained within the blood-vessels is generated there, or whether it is taken up from extraneous sources, to be conveyed by the current of the circulation to the excretory outlets. Now in favour of the first of these opinions it may be urged, that, as will appear hereafter (CHAP. XII., SECT. 3), Urea is *not* formed *only* from the disintegration of the living tissues, but that it is also generated at the expense of superfluous alimentary materials, which, having been introduced into the blood, and not being required to supply the wants of the system, pass into decomposition without ever having been converted into tissue. Such being the case, a part at least of the Urea that is eliminated from the blood may be considered as having been generated within the vessels; since it is very seldom that of the supply of nitrogenous aliment ingested by man, there is not some portion that may be considered superfluous. Now of that portion which has its origin in the disintegration of the tissues, the greater part may be set down to metamorphosis of the muscular substance, since it is found that muscular exercise has a special power of augmenting the quantity of urea in the urine; and the question arises, whether Urea is one of the immediate products of this metamorphosis, or whether some other compound is first generated, which is converted into urea after its absorption into the circulation. Now although it is impossible in the present state of our knowledge to answer

this question in either way with any degree of certainty, yet there is certainly a strong probability that the second of these views is the correct one; for, in the first place, no trace of urea has been found in the 'juice of flesh;' whilst, secondly, this juice contains a considerable amount of the substance (creatine), from which urea may be generated artificially (§ 60). That uric acid also may be converted into urea in the circulating blood, seems to have been distinctly proved by the experiments to be presently cited (§ 55). It appears most probable, therefore, that the products of the disintegration of muscle are received into the blood, not in the form of urea itself, but in that of kreatine or of some other compound, which is capable of being resolved into urea by further metamorphosis; and that the immediate source of urea, therefore, in the latter case as in the former, is one of the constituents of the circulating blood.

54. Next in importance to Urea, and taking its place as the predominating component of the urinary excretion of most animals below Mammalia, is *Uric Acid.* The small proportion, however, in which this substance normally presents itself in the urine of Man,—its usual amount being less than 1 part in 1000 of Urine, whilst that of Urea is from about 25 to 32 parts in 1000,—might seem to render it unnecessary to enter at length into its chemical peculiarities or its physiological relations. But although in the healthy system it may seem to perform a subordinate part, there can be no doubt whatever that in various disordered states of the body an augmented production of uric acid, or a deficient metamorphosis or elimination of it, or both conditions combined, exercise a very important influence, and become the sources of other perversions; and it is therefore a matter of great consequence to trace out, so far as is possible, the entire history of this substance, both chemical and physiological.—Pure uric acid occurs either in a glistening white powder, or in very minute scales, whose form, when they are examined by the microscope, is found to be distinctly crystalline, although the shape of the crystals is liable to considerable variation. As it is by the microscope, rather than by any chemical tests, that the presence of uric acid is most readily detected, and as its protean forms of crystallization, although easily reduced by the crystallographer to a determinate system, are liable to perplex those who have not the advantage of his scientific knowledge, it will be advantageous here to cite the description of them given by Prof. Lehmann. "Uric acid, when it gradually and spontaneously separates from urine, appears in most cases in the whet-stone form, that is, it forms flat tablets, which resemble sections made with the double knife through strongly bi-convex lenses, or rhombic tablets whose obtuse angles have been rounded. As the urinary pigment adheres very tenaciously to the uric acid, it is only rarely that these crystals are devoid of colour; and if we see a crystal presenting an extraordinary form and of a yellow colour, the probability is that it is a crystal of uric acid. On artificially separating uric acid from its salts, it often appears in perfect rhombic tablets, and even oftener in six-sided plates resembling those of cystine; when uric acid crystallizes very slowly, it forms elongated rectangular tablets or parallelopipeds, or rectangular four-sided prisms, with horizontal terminal planes; the latter are often grouped together in clusters; we have also barrel-shaped or cylindrical prisms, which are composed of the more rarely-occurring elliptic tablets; and finally saw-

like or toothed crystals, and many derivatives of these forms. If we cannot decide with certainty regarding the presence of uric acid from the form of a crystal, we must dissolve it in potash, place it under the microscope, and add a minute drop of acetic acid; we shall then always obtain one of the more common forms." * Uric acid is devoid of odour and taste; it requires 1800 or 1900 parts of hot water, and 14,000 or 15,000 parts of water at the ordinary temperature of 68°, to dissolve it; but it dissolves readily in solutions of the alkaline carbonates, phosphates, lactates, and acetates, abstracting some of the alkali from the salts; it is expelled from these solutions, however, by an excess of the free acids. Uric acid is one of the weakest class of acids; it does not redden litmus paper; it does not directly expel carbonic acid from carbonate of potash, but simply withdraws a portion of the alkali, leaving the remainder in the condition of a bicarbonate; and it does the same with a solution of basic phosphate of soda, changing its previously-alkaline into an acid reaction, by the production of a biphosphate.—According to the analysis of Bensch, the formula of Uric Acid (usually stated at 10 C, 4 H, 4 N, 6 O) is really 5 C, 1 H, 2 N, 2 O + H O. The acid has not been obtained, however, in its anhydrous state; and its existence must be admitted to be hypothetical.

55. Uric acid, when subjected to the operation of various reagents, may be made to undergo a great number of changes, and to give rise to a large series of organic compounds. Some of these metamorphoses it is important to notice here; as they throw light upon the phenomena of the living organism. Thus it is found that urea may be produced by the artificial oxidation of uric acid; and this in more than one mode. Thus, if four parts of uric acid be mixed with eight parts of moderately strong hydrochloric acid, and one part of chlorate of potass be gradually introduced, Urea is formed, together with a new compound termed Alloxan, which in its turn may be resolved by a further supply of oxygen into urea and oxalic acid, or, by still higher oxygenation, into urea and carbonic acid. So, again, when uric acid is boiled with peroxide of lead, there are formed, as the resultants of the process, an Oxalate of the protoxide of lead, Urea, and Allantoin; this last being a substance which naturally presents itself in the fluid of the allantois of the fœtal calf (being, in fact, the secretion of its temporary kidneys), and which there seems to take the place of urea, although its composition is represented by a very different formula (8 C, 5 H, 4 N, 5 O). The production of Urea from Uric acid is thus represented by Prof. Liebig:—

| | | C. | H. | N. | O. | | C. | H. | N. | O. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 equiv. hydrated Uric acid | = | 5 | 2 | 2 | 3 | = | 2 | 4 | 2 | 2 | = | 1 equiv. Urea |
| 2 equiv. Water | = | | 2 | | 2 | | 3 | | | 6 | = | 3 equiv. Carb. acid. |
| 3 equiv. Oxygen | = | | | | 3 | | | | | | | |
| | | 5 | 4 | 2 | 8 | | 5 | 4 | 2 | 8 | | |

Now it has been ascertained by the experiments of Wöhler and Frerichs,† that if urate of potash be injected in quantities of 30 or 40 grains into the blood-vessels of rabbits, no uric acid shows itself in the urine, but the

* "Physiological Chemistry," vol. i. p. 210.
† "Ann. der Chem. und Pharm." band lxv. pp. 338–342.

quantity of urea is enormously increased, and oxalate of lime makes its appearance; so that a metamorphosis of uric acid into urea must have taken place in the circulating current, and this probably by means of the oxidating process of respiration.* Further, there is evidence afforded by the phenomena of calculous disorders, that there is a natural alternation between the deposits of uric and of oxalic acids; the latter being found to replace the former, when more exercise is taken by the subjects of them, whilst a still greater amount of exercise favours the metamorphosis of the uric acid into urea, by the higher oxygenation which the augmented respiration will tend to produce.†—When Uric acid is dissolved in dilute nitric acid, and the fluid is evaporated until it assumes a reddish tint, the solution, being allowed to cool to 150°, and being then saturated with ammonia, deposits a substance which crystallizes in short four-sided prisms, that present a garnet-red hue by transmitted light, but have a cantharides-green lustre by reflected light. This substance has been named *Murexide*, on account of its reddish-purple colour, resembling that of the Tyrian dye which was obtained from a species of Murex; but it was long since maintained by Dr. Prout to be in reality a Purpurate of Ammonia; and this view of its composition, although contested for some time, is now generally admitted,—the Purpuric acid, or Murexan, being obtained in a separate form, and entering into combinations of other bases. Murexide is one source of the colours of the pink and lateritious sediments, which so frequently present themselves in the urine; these hues partly depend, however, upon the peculiar colouring principles of that secretion (§ 64).—It is by the formation of murexide that the presence of Uric acid is best determined chemically; for the purplish-red residue which its solution in nitric acid leaves on evaporation, suffices to distinguish it from every other organic substance, except perhaps caffeine; and whatever doubt may remain is dissipated by the development of a splendid violet tint on the addition of caustic potash, this being the result of the action of that substance on murexide.

56. Owing to the almost complete insolubility of Uric Acid in water, so long as it remains uncombined, it could not be a constituent of the urinary secretion, unless held in solution by some other substance. This substance appears from the researches of Liebig, which have been confirmed by other Chemists, to be phosphate of soda, which yields up a part of its base to form an acid urate of soda, and is itself converted into a superphosphate. This urate of soda is not possessed of any great solubility, especially in cold water; and thus it may be precipitated, if present in excess, when the temperature of the urine is lowered, although it was in a state of perfect solution at the time that the urine was voided. An augmentation of the normal amount of uric acid in the urine almost always takes place when there is any febrile disturbance in the system; and it may be so great as to prevent the whole of the acid from being

* According to Liebig ("Familiar Letters," p. 399), this process is to be likened to the reduction of the salts of the vegetable acids, the citrates, tartrates, malates, or to that of the lactates, to the condition of carbonates; for, he remarks, "it is well known that urea corresponds in composition to carbonic acid; being carbonic acid in which half the oxygen is represented and replaced by its equivalent of amide (N, 2H)." This view of its constitution, however ingenious, seems far from accordant with the *basic* character of urea.

† See Prof. Liebig's "Chemistry in its applications to Physiology and Pathology," 2nd edit. p. 137.

united with a base, so that free uric acid presents itself in the urine. It is very seldom, however, that such is the case; for the lateritious sediment deposited in diseases attended with fever, consists, according to Lehmann, not of amorphous uric acid as was long believed, nor of urate of ammonia as maintained by Dr. Golding Bird,* but chiefly of urate of soda, mixed with very small quantities of urate of lime and urate of ammonia. After urine has been discharged, however, for an hour or more, crystals of free uric acid may frequently be found in it; this being consequent upon a change in the constituents of the urine itself on exposure to the atmosphere, whereby lactic acid is developed in it, as has been demonstrated by Scherer. So, again, a deposit of urate of ammonia may present itself in urine that has been exposed to the air for a still longer period, and has undergone the alkaline fermentation; but it is very rare to find crystals of this salt in the urine of paraplegic patients which has become alkaline within the bladder, and still rarer to discover it in the urine which has been rendered alkaline by the general conditions of the system. As a general rule it may be stated, that no conclusions can be drawn respecting the amount of uric acid in the urine, from the formation of a sediment either of this substance or of one of its salts; since the deposition of this sediment will be determined by a number of conditions which affect its solubility, independently of those which occasion variations in the absolute quantity produced. Among these, not the least important is the amount of the watery portion of the secretion; since a diminution of this may occasion a precipitation of urate of soda or urate of ammonia on its cooling, although these salts were dissolved in it at the temperature of the body. So, again, the presence of lactic acid may occasion a precipitation of uric acid, although the latter has not been formed in excess. The peculiar conditions of the system which give rise to these deposits, will have to be considered hereafter (CHAP. XII., SECT. 3).

57. Tracing back the formation of Uric acid, as we have attempted to do in the case of Urea, we find ample evidence, in the first place, that it is not generated in the act of secretion, but that it pre-exists in the blood; as it has been detected there, not merely in diseased states of the system, in which either its elimination is checked, or its production is increased, or both conditions concur; but even, though in very minute quantity, in healthy blood.† Urate of soda is found in abundance in gouty concretions and tophaceous deposits; and it has been observed by Dr. G. Bird as a sort of efflorescence on the surface of the limbs of patients suffering under rheumatic gout.‡ It cannot be doubted that Uric acid is formed, either directly or indirectly, by the metamorphosis of the protein-compounds, whether this be consequent upon the disintegration of the living tissues, or upon the decomposition of superfluous alimentary materials; and we have seen that there is adequate evidence that it may be con-

* By Dr. Golding Bird, however, it is still maintained that uric acid normally exists in the urine in combination with ammonia, derived from the phosphate of soda and ammonia which he believes to be one of its ordinary constituents; and that in the deposits in question the urate of ammonia predominates, though he allows that the urates of soda and lime are also to be found.—See his "Urinary Deposits," 3rd. edit., pp. 78 and 128.

† See Dr. Garrod's Observations on certain pathological conditions of the Blood in Gout, Rheumatism, and Bright's Disease, in "Medico-Chirurg. Trans." vol. xxxi.

‡ Op. cit., p. 137.

verted into urea in the living body, as in the laboratory of the Chemist, whilst there is no corresponding evidence that urea can be converted into uric acid. When it is borne in mind, also, that uric acid is by far the *more general* of these two substances,—urea being almost peculiar to the Mammalian class which is remarkable for the fluidity of its urine, whilst uric acid, in combination with soda and ammonia, is the characteristic constituent of the semi-solid urine of the oviparous Vertebrata, as well as of that of many Invertebrate animals,*—there seems a strong probability that uric acid is one of the first products (if not actually the first) of that metamorphosis, and that urea is subsequently generated from it during its passage through the circulation.—That of the entire amount of uric acid generated in the system, a part is directly derived from the food, when this contains a superfluity of azotized compounds, appears from the experiments of Lehmann, who found that whilst he voided 11·24 grains of uric acid in twenty-four hours, whilst living upon a diet entirely unazotized,—this quantity therefore representing that which results from the 'waste' of the tissues alone,—he disengaged 15·7 grains when living upon a vegetable diet, 18·17 grains upon a mixed animal and vegetable diet, and 22·64 grains (or rather more than double the first amount) when his diet was exclusively animal. This, as will hereafter appear, is a point of considerable importance in the treatment of diseases attended with excessive production of uric acid. Scarcely a trace of uric acid has yet been detected in the muscles; but it has been recently found by Scherer in considerable quantity in the spleen, where it is accompanied by another substance nearly related to it in composition, which he has also obtained from the heart, both of man and of the ox. This substance, which has been termed *Hypoxanthine*, presents itself in the form of a white crystalline powder, which is soluble in 180 parts of boiling water, but requires 1090 parts of cold water for its solution, so that it is deposited on the cooling of a decoction of the substance of the spleen.† Its formula is 5 C, 2 H, 2 N, 1 O; and it thus contains 2 equiv. less of oxygen than hydrated Uric acid, into which it may very probably be metamorphosed.

58. Uric acid is almost uniformly replaced in the urine of herbivorous animals by an acid of very different composition; which, having been first distinguished by Liebig in the urine of the horse, was named by him *Hippuric acid.* His subsequent inquiries satisfied him that it also exists normally, though in comparatively small quantities, in the urine of Man, especially after the use of vegetable food; and if it is ever entirely absent, it is probably so only when the diet is exclusively animal,—just as it is absent from the urine of calves while suckling, being replaced in them by uric acid. Hippuric acid crystallizes from hot solutions in the form of minute spangles, or of larger, obliquely-striated, four-sided prisms, terminating at the ends in two flat surfaces; the elementary form, however, which is best

* A substance termed Guanine, which has weak basic properties, and whose formula is 10 C, 5 H, 5 N, 2 O, has been discovered by Unger in guano, which is the mingled urinary and fœcal excrement of sea-fowls; it has been recently discovered also in the excrements of spiders, by Will and Gorup-Besanez; and they think it probable that a substance which they find in the urinary organs of the river craw-fish and of the fresh-water mussel, is identical with this. Dr. J. Davy believed that the urinary secretion of scorpions and spiders consists for the most part of xanthine or 'uric oxide' (§ 65); but the substance which he discovered was more probably guanine.

† "Ann. der Chem. und Pharm.," band lxxiii. p. 328.

seen in crystals obtained by slow evaporation, is a vertical rhombic prism. This acid is devoid of smell, has a slightly bitter but not an acid taste, dissolves in 400 parts of cold water, and very freely in hot water, and reddens litmus-paper powerfully. Its formula is 18 C, 8 H, 1 N, 5 O, + HO; and it is thus remarkable for the almost complete absence of nitrogen and for the large proportion of carbon, a constitution which approximates it closely to the biliary compounds. When boiled with concentrated hydrochloric acid, this substance undergoes a very remarkable change; being resolved into Glycine or gelatin-sugar (§ 33), and Benzoic acid, probably in the manner following, one additional equivalent of water being alone required.

| | C. | H. | N. | O. | | C. | H. | N. | O. | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 equiv. hydrated Hipp. acid = | 18 | 9 | 1 | 6 | = | 4 | 5 | 1 | 4 | = 1 equiv. Glycine |
| 1 equiv. Water . . = | | 1 | | 1 | | 14 | 5 | | 3 | = 1 equiv. Benzoic acid. |
| | 18 | 10 | 1 | 7 | | 18 | 10 | 1 | 7 | |

Various other reagents will cause the production of benzoic acid at the expense of hippuric; and this change takes place during the putrescent fermentation of urine of which hippuric acid is a constituent. According to the view originally suggested by Strecker, hippuric acid is really to be considered as a 'conjugated acid,' formed by the union of benzoic acid, which he supposed to pre-exist in it, with an adjunct composed of 4 C, H 3, 1 N, 2 O, which in separating takes to itself an equiv. of water and forms glycine; and this view (although since abandoned by Strecker himself) is considered by Lehmann as the most probable, especially since one of the biliary acids (§ 68) appears to have an analogous constitution, glycine being there also generated by the action of acids upon it.* The close relation of Hippuric to Benzoic acid is further indicated by the well-established fact, that not only benzoic acid, but also the oil of bitter almonds, and cinnamic acid, which have the same compound radical *benzoyl*, are converted into hippuric acid in the body.†

59. The remarkable predominance of Carbon in Hippuric acid, and its limitation to the urine of animals which partly or entirely subsist on vegetable food, seem at first sight to support the idea of its discoverer, that it is mainly formed at the expense of the non-azotized articles of food. But this view is directly opposed by the following facts stated by Prof. Lehmann:—in the urine of patients suffering under fibrile diseases, and taking but a very small amount of food of any kind, the amount of hippuric acid in the urine is increased; the urine of tortoises which had

* See his "Physiological Chemistry," vol. i. pp. 189-192.—The term 'conjugated acid' is applied to a class of compounds recently discovered, in which certain organic acids unite with other and more basic bodies without losing anything of their acidity, still saturating the same quantity of base as if the organic 'adjunct' did not exist. This adjunct, which follows the acid as an integral constituent through all its combinations, exerts an essential influence on its physical, and even on many of its chemical properties. (Op. cit., p. 184.)

† It was at one time considered, that the hippuric acid which appears in the urine after the administration of the benzoic, is formed at the expense of the uric; and it was proposed by Dr. A. Ure to administer benzoic acid, when a tendency to the increased production or to the precipitation of uric acid shows itself in the system, in order that it may be eliminated in the more soluble form of hippuric acid. But the results of analysis do not bear out this view; the quantity of uric acid in the urine, after the administration of benzoic acid, not showing any perceptible diminution.

been kept fasting for more than six weeks, still contained hippuric acid; and the urine of diabetic patients restricted to a purely animal diet also exhibits it. Further, it is occasionally to be detected, as we learn from Dr. G. Bird (Op. cit. p. 195), in the urine of infants at the breast. Moreover, since it has been ascertained by Guckelberger that the azotized histogenetic substances, when treated with oxidizing agents, yield benzoyl-compounds; and since albuminous as well as gelatinous substances yield glycine (§ 33); it would appear highly probable that Hippuric acid is to be regarded as one of the products of their decomposition, and that it is not in any way derived from non-azotized articles of food. The peculiar richness in carbon which distinguishes this substance, is by no means opposed to such a view; since an equal proportion is found in biliary matters, and also in the colouring matters of the urine, the materials of both of which are unquestionably derived in great part from the metamorphosis of the azotized tissues. And when all the facts of the case are taken into account, it does not seem difficult to account for the peculiar proneness of this acid to appear in the urine of herbivorous animals; since the abundance of the carbonaceous elements of their food will tend to prevent the oxidation of the highly-carbonized products of the waste of the tissues, and will thus leave these to be got rid of through the liver and kidneys. And this view derives confirmation from the fact, that when stall-fed animals, in whose urine hippuric acid abounds, are subjected to exercise, the hippuric acid is more or less completely replaced by benzoic acid, which contains a smaller proportion of carbon. Further, when hippuric acid presents itself in unusual amount in states of disease, its appearance is generally coincident with imperfect action, either of the lungs, skin, or liver, which are the three great emunctories of carbonaceous matters; so that its presence in the urine may be considered as indicating that a larger amount of carbonaceous matter is present in the circulation, than the respiratory process, with the cutaneous and biliary excretions, can remove. That there is generally a deficiency of urea in the urine, when hippuric acid makes its appearance in unusual quantity, seems an additional indication that these two substances are derived from the same ultimate sources.—Hippuric acid has not yet been detected in Human blood, or in any other secretion than the urinary; but it has been discovered in the blood of the Ox.

60. Two substances have been recently detected in the urine, which are of very considerable interest, as tending to connect the formation of the components of this secretion with the disintegration of the azotized tissues, more intimately than the facts previously known appeared to justify. These substances are termed *Creatine* and *Creatinine*, designations which were conferred upon them from their presence in the 'juice of flesh,' of which they are constant constituents, and from which they may be most readily obtained.—*Creatine* is a neutral substance, presenting itself in the form of colourless transparent crystals, which, when they are deposited from a concentrated solution, are long and acicular, but when formed more slowly are short and thick; these crystals contain two equiv. of water of crystallization, which they lose when heated to 112°, themselves becoming opaque. It is very soluble in hot water, but requires 74·4 parts of cold water to dissolve it. It is of a bitter, strongly pungent taste; and irritates the pharynx. Its formula is 8 C, 9 H, 3 N, 4 O. The proportion

which Creatine bears to the whole mass of flesh is very small, and is subject to considerable variation in different animals, as well as (probably) in different states of the same. Thus in 1000 parts of ox-heart Dr. Gregory found from 1·37 to 1·42 parts of creatine; in the same amount of the flesh of the cod, 0·93 in one experiment, and 1·7 (or nearly double) in the other; in the flesh of a pigeon, 1·82 parts; and in that of a skate no more than 0·60 parts. It has not been detected in the substance either of the brain, liver, or kidneys; and its proportion in the urine is so small that this has not yet been determined, its place being almost entirely occupied by creatinine. When creatine is boiled with alkaline solutions or with baryta-water, it is resolved into Urea and a new substance termed *Sarcosine;* and for the reasons already given (§ 53), it seems likely that some such change as that represented by the following formula takes place in the living body.

$$\begin{array}{rcccc} & \text{C.} & \text{H.} & \text{O.} & \text{N.} \\ \text{1 equiv. crystallized Creatine} = & 8 & 11 & 3 & 6 \end{array} = \left\{\begin{array}{ccccl} \text{C.} & \text{H.} & \text{O.} & \text{N.} & \\ 2 & 4 & 2 & 2 & = \text{1 equiv. Urea} \\ 6 & 7 & 1 & 4 & = \text{1 equiv. Sarcosine.} \\ \hline 8 & 11 & 3 & 6 & \end{array}\right.$$

It is true that Sarcosine does not make its appearance, as such, in the solids or fluids of the body; but there is reason to think that it may be rapidly decomposed, for by the addition of one equiv. of water, it would become isomeric with lactate of ammonia, and may not impossibly, therefore, be further reduced by the respiratory process, in the same manner as are the lactates generally (§ 49). Although Creatine dissolves unchanged in dilute acids, it becomes converted, by heating with strong acids, into *Creatinine*, giving off two equiv. of water. This substance, which also forms prismatic crystals, moderately soluble in water, differs considerably from creatine in its chemical relations; for it has a strong alkaline reaction, even separating ammonia from its salts, and serves as a powerful base to acids, with which it forms soluble and readily crystallizable salts. It also forms double salts with various metallic compounds, in a manner very analogous to ammonia; and among these is the white crystalline compound with chloride of zinc, whose production in the urine, upon the addition of that substance, first led to the detection of creatine and creatinine as constituents of the secretion.

61. The relations of these two substances, both chemical and physiological, pretty clearly indicate that Creatinine is to be regarded as a derivative from Creatine; for whilst the latter predominates in the juice of flesh, almost to the exclusion of the former, the former predominates in the urine almost to the exclusion of the latter. Moreover, as we have just seen, creatinine may be produced by a very simple process from creatine; and this change takes place in urine even after it has passed out of the body, for, when putrid, this fluid is no longer found to contain creatine, the whole of that substance having undergone metamorphosis. On the other hand, creatinine cannot be converted into creatine by any known chemical process; and there is no evidence that such conversion ever takes place in the living body. Looking, then, to the nature of creatine itself, to its relations to creatinine and to urea, and to the fact that it is a constituent of urine, there can be no doubt whatever, that so far from being an alimentary substance, whose presence in the muscular tissue

serves an important purpose in nutrition,* it is from the first destined to excretion, and is received back into the circulation by absorption from the muscular tissue, to be eliminated, chiefly under different forms, through the kidneys. As it is found so constantly in the juice of flesh, more abundantly in that of wild and hunted animals than in that of tame and domesticated races, and most abundantly of all in the substance of that never-resting muscle, the heart, it may be fairly presumed to be a product of the disintegration of the muscular tissue; and, so far as we at present know, it is the *first* product of that metamorphosis. Of the mode in which that change is effected, however, or of the nature of the complementary substances into which the protein-compound resolves itself, we are at present entirely ignorant.

62. Some light upon this last point, however, may possibly be derived from the study of the other constituents of the 'juice of flesh.' In this Liebig occasionally detected an acid, to which he has given the name of *Inosic;* this is not crystallizable, but forms a syrupy fluid readily dissolving in water, and possesses an agreeable taste of the juice of meat. It reddens litmus strongly, and forms crystallizable salt with bases. Its formula is considered to be $10\ C,\ 6\ H,\ 2\ N,\ 10\ O + H\ O$; and it is thus remarkable for the large proportion of oxygen which it contains. It has not been detected either in the urine or in any other excretion; and if its absence in the excretory fluids should be substantiated, it must evidently undergo some metamorphosis in its passage from the muscles to the final outlets of the products of their disintegration. Dr. G. Bird has pointed out (Op. cit. p. 37) that the constituents of Inosinic acid are exactly those of Acetic acid, Oxalic acid, and Urea;

$$\begin{array}{lcccc} & C. & H. & N. & O. \\ 1\text{ equiv. hydrated Inosinic acid} = & 10 & 7 & 2 & 11 \end{array} = \left\{\begin{array}{cccccl} C. & H. & N. & O. & & \\ 4 & 3 & & 3 & = & 1\text{ equiv. Acetic acid} \\ 4 & & & 6 & = & 2\text{ equiv. Oxalic acid} \\ 2 & 4 & 2 & 2 & = & 1\text{ equiv. Urea,} \\ \hline 10 & 7 & 2 & 11 & & \end{array}\right.$$

and suggests this as a possible resolution of the first-named substance, the acetic and oxalic acids being carried off by oxidation through the lungs, and the urea being removed by the kidneys. It is some confirmation of this view, that acetic acid has been found by Scherer in the juice of flesh. Inosinic acid, however, would not appear to be one of the necessary products of the disintegration of muscle; for it is frequently absent altogether, and, when it is present, its quantity is very variable.—Two other organic acids have been observed by Liebig in the juice of flesh, besides the lactic (§ 48); but little is known of their composition. From his latest inquiries, however, it appears that the juice of flesh immediately on being expressed has no acid reaction, but that this very

* This doctrine, advanced by Prof. Liebig in his important treatise on "The Chemistry of Food," is a specimen of the absurdities into which even so eminent a Chemist may be betrayed, when he abandons that path of purely chemical research in which he is approached by few, to speculate upon a subject of which he is comparatively ignorant, and on which the opinions of scientific Physiologists have a much higher claim to consideration.—Both Chemists and Physiologists, however, are now so generally in accordance with regard to the excrementitious character of Creatine, that the original doctrine of Prof. Liebig will probably be soon forgotten.

speedily presents itself on exposure of the fluid to the atmosphere; from which it may be inferred that these acids do not originally exist in the fluid, but that they are formed there by a fermentation-process subsequently to its removal from the body. The recent discovery of *Inosite*, or muscle-sugar (§ 46), appears to afford a connecting link by which we may account for the production of lactic acid in this situation.

63. It will the better serve to show the remarkable predominance of Nitrogen in nearly all of these excrementitious matters now described, if we arrange their respective formulæ in a tabular mode, and compare the *per-centages* of that element which they severally contain.

| | Carbon. | Hydrogen. | Nitrogen. | Oxygen. | Per-centage of Nitrogen. |
|---|---|---|---|---|---|
| Albumen { Liebig | 49 | 36 | 6 | 14 | } 15·67 |
| Albumen { Mulder | 40 | 31 | 5 | 12 | |
| Urea | 2 | 4 | 2 | 2 | 46·67 |
| Uric Acid | 5 | 2 | 2 | 3 | 33·33 |
| Hippuric Acid (hydrated) | 18 | 9 | 1 | 6 | 7·82 |
| Inosic Acid (hydrated) | 10 | 7 | 2 | 11 | 15·30 |
| Allantoine (hydrated) | 8 | 5 | 4 | 6 | 35·44 |
| Creatine | 8 | 9 | 3 | 4 | 32·06 |
| Creatinine | 8 | 7 | 3 | 2 | 37·17 |

Thus we see that whilst the proportion of nitrogen in Inosic acid is almost precisely the same as in Albumen, the proportion of nitrogen in Uric acid, Allantoine, Creatine, and Creatinine, is *more than double* that which Albumen contains, whilst that of Urea is almost exactly *triple;* on the other hand, the per-centage of nitrogen in Hippuric acid is *exactly half* that which is found in Albumen. Again, the per-centage of carbon in Hippuric acid (60·33) considerably exceeds that which Albumen contains (54·88), and is no less than *three times* as great as that which exists in Urea (20·0).

64. Before quitting these characteristic components of the Urinary secretion, it will be desirable to mention certain other organic substances, of which some are constantly present in it, whilst the occurrence of others is exceptional or abnormal.—Chemists have been in the habit of designating under the general term *Extractive Matters,* substances which, whether they are produced by the reagents employed, or exist preformed in the animal fluids, are so deficient in characteristic properties, that they are not capable of being distinguished by analytical processes, or of being separated and exhibited in a pure state. With the progress of science, however, one substance after another has been withdrawn from this group; thus by the more attentive study of the extractive matters of the Urine, creatine, creatinine, and hippuric acid have been found among its components; and the extractive of the Blood has already yielded Mulder's binoxide and tritoxide of protein (§ 30), and will probably afford many more substances equally capable of being separately and characteristically distinguished. The Extractive matters must therefore be regarded, according to the just remark of Lehmann, as important factors in the metamorphosis of animal tissue, both progressive and retrograde, and deserve the most careful and attentive Chemical examination. Among the extractives of the Urine, have been usually ranked the *Colouring Matters;* the study of which, for reasons enumerated by Lehmann (Op. cit. p. 318), is attended with peculiar difficulties. It was suggested by

Dr. Prout that two distinct pigments probably exist; and this view is to a certain extent confirmed by the recent investigations of Scherer* and Heller.† These, however, seem to indicate that there is originally but a single pigment (the *uroxanthin* of Heller), probably derived from the hæmatin of disintegrated blood-corpuscles (or possibly from the pigmentary matter of the nerve-vesicles, which may itself be derived from the blood-corpuscles, § 31); but that this pigment may be very easily decomposed into two substances, differing in their respective amounts of carbon and hydrogen. One of these, termed by Heller *uro-glaucin*, forms a dark blue powder, which, when dried, possesses a coppery lustre and dissolves in alcohol with a splendid purple colour. The other colouring substance, which may be generated by the action of hydrochloric and other acids upon the ordinary urine-pigment, is of a yellowish pink hue when dissolved in alcohol, and specially attaches itself to the uric-acid salts, which, when they are deposited from the urine, carry it down with them, just as alumina carries down the colouring matter of cochineal; this substance (the *uro-erythrine* of Simon, the *ur-rhodin* of Heller) was long since termed *purpurine*‡ by Dr. G. Bird, and by this name it may be most conveniently designated. The urine-pigment as a whole is remarkable for the large proportion of carbon, 58½ per cent, which it contains; in the purpurine generated by the action of hydrochloric acid on urine, the proportion of carbon is 62½ per cent; but in the urine of patients suffering under febrile disorders or organic disease of the liver, in which a very large amount of purpurine exists, and in which bile-pigment (a still more highly carbonized substance, § 70) is very commonly present likewise, the proportion of carbon has been found to rise even to 65¾ per cent. The pathological conditions under which the amount of this carbonaceous pigment increases, are such as to indicate that the elimination of carbon by the liver, lungs, and skin is not being performed with its due activity; and the superfluity is thus thrown upon the kidneys for excretion.§—There seems no doubt that even normal Urine contains Sulphur in an unoxidized state; and the inquiries of Prof. Ronalds have led him to the conclusion, that this element, together with a small quantity of Phosphorus, is contained in a peculiar compound which forms part of the so-called 'extractive.' This compound has not yet been obtained in a separate form; but it furnishes the medium for the elimination of from at least 3 to 5 grains of sulphur in the twenty-four hours. The sulphur and phosphorus set free by the disintegration of the albuminous tissues, are for the most part oxidated in the system, and carried out of it in the form of sulphuric and phosphoric acids, in union with bases. But as we shall hereafter see (§ 69), a provision exists in the biliary excretion, for carrying off a large amount of sulphur in an unoxidized state; and it would appear as if the urine became the vehicle for whatever unoxidized sulphur may remain to be eliminated. The

* "Ann. der Chem. und Pharm." band lvii. pp. 180, 195.

† "Arch. fur Chemie und Mikrosk," band ii. pp. 161, 173.

‡ It is important to bear in mind that this substance has no relation whatever to *murexide* (§ 55), which was termed *purpurate of ammonia* by Dr. Prout, under the influence of an erroneous view of its constitution.

§ See Dr. Golding Bird's "Urinary Deposits," 3rd edit. pp. 171–177, and CHAP. XII. SECT. 3, of the present volume.

normal presence of this sulphur-extractive in the urine, has an interesting relation to the occasional or abnormal occurrence of the highly sulphurized substance known as Cystine (§ 66).

65. Among the organic compounds whose occurrence in Human urine is abnormal, we may first mention *Xanthine* or *Uric oxide*, which is a very rare constituent of calculi and of sedimentary deposits. This seems to be a neutral substance, having no action on vegetable colours, and not being yet known to enter into combination with either acids or alkalies. When freshly precipitated it presents itself as a white powder, which is neither crystalline nor gelatinous; and when dried it forms pale, yellowish, hard masses, which, on being rubbed, assume a waxy brightness. The calculi composed of this substance closely resemble those formed of uric acid, for which they are generally mistaken; they may be distinguished, however, by the well-marked salmon or rather cinnamon tint presented by their sections, and by the insolubility of their substance in a weak solution of carbonate of potass, which dissolves uric acid.* It is soluble, however, in the fixed alkalies and ammonia, as also in nitric and sulphuric acids. As no compounds have yet been obtained, by which its combining equivalent can be determined, the formula 5 C, 2 H, 2 N, 2 O, must be considered as representing nothing more than the per-centage composition of its elements; and although this only differs from that of hydrated Uric acid in the want of a single equiv. of oxygen, yet all attempts to generate either from the other, or to obtain urea from uric oxide, have hitherto failed. So, also, it seems to differ from Hypoxanthine (§ 57) only in containing one more equiv. of oxygen; but no real relation has been shown to exist between these substances.—Of the conditions under which Xanthine is formed in the living body, it is impossible at present to form the slightest idea. Strahl and Lieberkühn believe that they have discovered it in ordinary Human urine; but the substance which they describe seems rather to be *Guanine* (§ 57, *note*), which, when first discovered, was mistaken for Xanthine, but which differs from it in composition and properties, and is readily distinguished from it by its solubility in hydrochloric acid. Guanine is a yellowish-white crystalline powder devoid of odour or taste, insoluble in water, and having no action on vegetable colours; it serves, however, as a base to acids, though its salts are very unstable; and its formula is 10 C, 5 H, 5 N, 2 O + H O. Guanine appears, from the researches of Will and Gorup-Besanez,† to be one of the characteristic constituents of the urinary secretion in Invertebrated animals; and if it should prove to be of constant or even of frequent occurrence in Human urine, the fact will be one of no little interest. No doubt can be entertained, that Xanthine and Guanine are both of them to be regarded as products of the metamorphosis of the azotized tissues.

66. A substance is occasionally found in Urinary calculi, and also in sedimentary deposits, which is remarkable for the large proportion of Sulphur—amounting to 26·66 per cent—included in its composition. The substance, termed *Cystine*, occurs in the form of colourless, transparent, hexagonal plates or prisms, is devoid of taste or smell, is insoluble

* See Dr. Golding Bird's "Urinary Deposits," pp. 164–8.

† "Ann. der Chem. und Pharm." band lxix. p. 117.

in water and alcohol, and has no action on vegetable colours; but it serves as a base to oxalic and the mineral acids, forming with them saline combinations, most of which are crystallizable. Its formula is 6 C, 6 H, 1 N, 2 S, 4 O; but no probable account can yet be given of the mode in which these equivalents are combined and arranged. It is very readily soluble in ammonia, but forms no compound with it, so that on the evaporation of the ammonia it crystallizes in its characteristic tablets; and by this character, as well as by the peculiar and disagreeable odour which it emits in burning when heated on platina-foil, cystine may be readily distinguished from any other urinary sediment. Though its occasional presence in urine has not been noticed by many observers, yet it would appear sometimes to exist there in considerable quantity, forming a nearly white or pale fawn-coloured pulverulent deposit, much resembling the pale variety of urate of ammonia, for which it is liable to be mistaken; and so copious may this be, that Dr. G. Bird states that he has seen a 6 oz. bottle full of urine let fall by repose a sediment of cystine to the depth of half an inch. According to this excellent observer, the presence of cystine in the urine may often be detected by microscopic examination, where it forms no distinct deposit; and this especially in strumous subjects, a class which he regards as peculiarly subject to cystin-urea. It has also been observed in chlorotic subjects. There can be no doubt that cystine is one of the forms under which the products of the metamorphosis of the albuminous tissues present themselves; and its composition is not so far removed from that of the ordinary results of that metamorphosis, as would at first sight appear. For as Dr. G. Bird has pointed out,

| | C. | H. | N. | O. | S. | | C. | H. | N. | O. | S. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 eq. Urea . . = | 2 | 4 | 2 | 2 | 0 | = | 12 | 12 | 2 | 8 | 4 | = 2 eq. Cystine |
| 2 eq. hydrated Uric Acid = | 10 | 4 | 4 | 6 | 0 | | | | 4 | | | = 4 eq. Nitrogen. |
| 4 eq. Sulphuretted Hydrogen = | | 4 | | | 4 | | | | | | | |
| | 12 | 12 | 6 | 8 | 4 | | 12 | 12 | 6 | 8 | 4 | |

It is a very remarkable circumstance that the composition of Cystine should present an extremely close relation to that of Taurine, the sulphurized constituent of the bile (§ 69); their respective per-centages of hydrogen, nitrogen, and sulphur being almost precisely identical, and the difference lying only in those of carbon and oxygen; as will be seen from the following comparison:—

| | Cystine. | Taurine. |
|---|---|---|
| Carbon . | 30·00 | 19·20 |
| Hydrogen . | 5·00 | 5·60 |
| Nitrogen . | 11·66 | 11·20 |
| Oxygen . | 26·67 | 38·40 |
| Sulphur . | 26·67 | 25·60 |
| | 100·00 | 100·00 |

Here, then, we have another marked example of the vicarious nature of the urinary and biliary excretions; the former taking upon itself the removal, under peculiar circumstances, of a product whose components should normally find their way into the latter.*

* See, on the whole of this subject, the excellent treatise of Dr. Golding Bird on "Urinary Deposits," already referred to.

67. We now pass from that group of Excretory matters of which Nitrogen is the predominating constituent, to that of which *Carbon* and *Hydrogen* are the principal components; and as the former are the characteristic ingredients of the Urinary excretion, so are the latter of the Biliary. Regarding the organic compounds we have now to consider, however, our knowledge is far less definite and satisfactory than it is respecting those which have been already passed in review; and this arises from several causes, among which may be more particularly mentioned the great facility with which they are decomposed, both spontaneously, and by the operation of reagents; so that it is by no means easy to say, in many instances, whether a given substance, extracted from the bile by analytical operations, pre-existed in it, or has been subsequently formed under the treatment to which that fluid has been subjected. There has consequently been a vast discrepancy of opinion amongst Chemists, with regard to the constitution of this excretion; some having regarded as original components, what others have considered as secondary; and the number of proximate constituents having been ranked high by some, whilst others have reduced it to no more than four or five.—According to Strecker, whose researches have been more successful, and whose views seem more trustworthy, than those of any other chemist, we are to regard the proper biliary matter as chiefly composed of two substances, which are regarded by Lehmann as 'conjugated acids' (§ 58, *note*), formed by the union of one and the same acid, the true *Cholic*, with Glycine and Taurine respectively, and hence termed by him the Glycocholic and the Taurocholic.

68. This *Cholic* acid (the *cholalic* of Strecker), which was first obtained in a state of purity by Demarçay, is a fatty or rather a resinous acid, from which nitrogen is altogether absent, whilst oxygen is present in it in only a small proportion, its formula being 48 C, 39 H, 9 O. It forms tetrahedral or more rarely square octohedral crystals, which effloresce on exposure to the air; it is soluble in 750 parts of boiling water, and in 4000 parts of cold, and dissolves very readily in alcohol, especially when heated. Its taste is bitter, leaving a faint sweetish after-taste. It fuses at 383°; if heated above that temperature, it loses its atom of basic water, and is converted into *choloidic* acid; and if heated to 554°, it becomes converted into *dyslysin*, a resinous substance having no acid properties. These changes may also be effected by boiling cholic acid with hydrochloric acid. The acid reaction of this substance is sufficiently strong to redden litmus, and to enable it, with the aid of heat, to expel the carbonic acid from solutions of the alkaline carbonates. The salts which it forms possess a bitter and at the same time a slightly sweet taste; they are all soluble in alcohol, but water dissolves only the cholates of the alkalies and of baryta. The salts of choloidic acid are perfectly isomeric with those of cholic acid; but it is curious that the former acid is displaced even by carbonic acid, although, with the aid of heat it decomposes the carbonates. Cholic acid may be recognized wherever it occurs,—whether combined with its adjuncts as a conjugated acid, or metamorphosed into the choloidic,—by the excellent test devised by Pettenkofer, founded upon its peculiar reaction with sugar and sulphuric acid; for if, to the fluid suspected to contain bile, there be first added a little solution of sugar, and pure sulphuric acid be then added by drops, a yellowish colour is

produced, deepening to a pale cherry, then to a carmine, and lastly to an intense violet tint, if bile be present. This test may therefore be applied to determine the presence or absence of the characteristic components of bile; and we shall hereafter notice some of the results of its application. When choloidic acid is distilled with nitric acid, it yields the volatile acids of the butyric and succinic acid groups, as does also oleic acid under similar treatment; and it has been recently pointed out by Schultze,* that oleine, when submitted to the bile-test, presents nearly the same reaction as bile; so that a special relation seems to exist between them. Cholic acid does not naturally occur in its isolated state, and can only be obtained by processes that have the effect of separating it from the nitrogenous substances with which it is normally conjugated.—The compound of Cholic acid and Glycine (§ 33), termed by Lehmann *Glycocholic* acid, but formerly known *par excellence* as the *bilic* or *cholic* acid, is the principal organic constituent of the bile of most animals; being united in that fluid with potash and soda as bases, and not having a sufficiently strong acidity to prevent its salts from possessing an alkaline reaction. This acid crystallizes in extremely delicate needles, which remain unchanged at 277°; it has a bitterish-sweet taste, dissolves in 120·5 parts of hot water, and 303 of cold, and is readily soluble in spirit. By prolonged boiling with alkalies or baryta-water, it is resolved into cholic acid and glycine; whilst if boiled with concentrated sulphuric or muriatic acids, it is resolved into choloidic acid and glycine. Its alkaline salts, which form 'crystallized bile,' are very soluble both in water and spirit, and separate from their alkaline solutions on the addition of ether, in large glistening white clusters of radiating needles, resembling wavellite. These burn, when heated, with a bright smoky flame. The formula of this acid is 52 C, 42 H, N, 11 O + HO; and, with the addition of another equivalent of water, is exactly that of cholic acid + glycine.

69. The other conjugated acid of bile, termed by Lehmann the *Taurocholic* (but also named *choleic* acid, and formerly known as *bilin*), has not yet been separated in a state of perfect purity, that is to say, free from glycocholic acid; it cannot be obtained in a crystalline state, and it is more soluble in water than glycocholic acid, whilst its acid properties are far weaker. It dissolves fats, fatty acids, and cholesterin in large quantities; and is thus the cause why glycocholic acid is not precipitated, when acids are added to fresh bile. When boiled with alkalies, it is resolved into taurine and cholic acid; and when boiled with the mineral acids, into taurine and choloidic acid. Its formula, as deduced from the composition of its salts, is 52 C, 45 H, 1 N, 2 S, 14 O; and this with an additional equivalent of water, corresponds to cholic acid + taurine. The alkaline taurocholates, which are the forms under which this acid exists in the bile, dissolve readily in water and alcohol; they have no reaction on vegetable colours, and have a sweet taste with a bitter after-taste; when heated, they melt and burn with a bright smoky flame. Although they may be kept for some time in solutions exposed to the air, without decomposition, provided they be pure, yet they are very readily affected by the presence of certain nitrogenous substances, such as mucus; and taurine is then set free, with alkaline cholates and choloidates.—The

* Canstatt's "Jahresbericht," 1850, p. 101.

substance now designated *Taurine* (formerly known as *biliary asparagine*) is a very peculiar neutral compound, which crystallizes in colourless, regular, hexagonal prisms, with four and six-sided sharp extremities. It is hard, craunches between the teeth, has a cooling taste, resists the action of the atmosphere, dissolves in $15\frac{1}{2}$ parts of water and 573 of dilute alcohol, and has no action on vegetable colours. It dissolves, without undergoing change, even at the boiling point, in the mineral acids, but forms no compounds with them; hence it cannot be properly considered as a base. The most remarkable peculiarity in its composition is the large proportion of Sulphur which it contains, this amounting to 25·6 per cent; and yet, notwithstanding that this substance had been analyzed by Gmelin, Demarçay, Pelouze, and Dumas, the presence of this element was overlooked, until it was discovered by Redtenbacher.* It may be made evident by the development of sulphurous acid, when taurine is inflamed in air; and in this manner, when the presence of one of the conjugated biliary acids has been detected by Pettenkofer's test, it may be determined to be the tauro-cholic. When taurine is boiled with caustic potash, it developes ammonia, and leaves a residue consisting solely of sulphurous and acetic acids in combination with potash. It is thought probable by Lehmann, that the sulphur of Taurine already exists in an oxidized condition, since it cannot be recognized in this substance by any of the ordinary fluid oxidizing agents. Taurine has never been found in an isolated state in healthy bile, although, as just now pointed out, it is set free by the spontaneous decomposition of the tauro-cholates. It must undoubtedly be regarded as one of the products of the metamorphosis of the albuminous tissues; but of the mode in which it is generated, no account whatever can be given.

70. The colouring matter of the Bile, or *Bile-pigment*, is a substance peculiarly difficult to investigate satisfactorily, owing especially to the very small quantity in which it occurs, and to its extreme instability. The most frequent form under which it presents itself, is that of a brown, non-crystalline powder, devoid of taste and smell, insoluble in water, very slightly soluble in ether, and more so in alcohol, to which it communicates a distinct yellow tint; this substance, the *cholepyrrhin* of Berzelius, the *biliphæin* of Simon, constitutes a large part of most biliary calculi, in which, however, it exists in a state of insoluble combination with lime. When it is dissolved in alkaline solutions, these, which are at first of a clear yellow, become, by exposure to the air, of a greenish-brown tint; and it is on this modification, the consequence probably of a higher oxidation, that the well-known changes of colour which occur in some of the animal fluids are dependent. The yellow alkaline solution, when treated with nitric acid, becomes first green, then blue (which hue, however, can hardly be detected in consequence of its rapid transition into violet), and then red; after a considerable period, the red again passes into a yellow colour, but the nature of the substance is then entirely changed. When the yellow alkaline solution is treated with hydrochloric acid, the pigment is precipitated with a green tint; this precipitate forms a red solution with nitric acid, and a green solution with the alkalies, and appears to be perfectly identical with the green modification of bile-pigment. When

* "Ann. der Chem. und Pharm.," band lvii. pp. 170–174.

acids are added to fresh bile, a green colour is produced, if oxygen be present, but not if it be excluded. Bile-pigment is occasionally found in the urine in large quantities, when its secretion by the natural channel is prevented; and it may be readily recognized by the nitric acid test. There is much uncertainty in regard to the precise composition of this substance, for the reasons already specified; the analyses which have been made of it, however, indicate that it is remarkable for the enormous proportion of carbon which it contains, this being as much as 68 per cent., and thus exceeding the proportion of that element in the black pigment of the eye, and in abnormal melanic deposits; it contains also about 8 per cent of nitrogen.—The bile of the Ox contains a green pigment which seems to be distinct from the preceding, not undergoing changes of colour when treated with nitric acid, and containing little or no nitrogen; this was considered by Berzelius to be identical with the chlorophyll of plants, and was designated by him as *biliverdin;* it does not seem, however, to be present in human bile. Another pigmentary substance has been discovered in bile, however, which is distinguished by its crystalline form, and by its reddish yellow hue; this was named by Berzelius *bilifulvin.*—The source of these colouring-matters is probably to be looked for, as already pointed out (§ 31), in the hæmatin of the red corpuscles; which undergoes changes, after their disintegration has commenced, that show a decided approximation to them. And it is a most important confirmation of this view, that hæmatin, when effused in situations where it can be acted-on by the air, exhibits most of the shades of colour which have been mentioned as characteristic of biliphæin; as is seen in the ordinary case of a cutaneous ecchymosis. With regard to the place in which the actual transformation occurs, however, we are entirely ignorant; for although bile-pigment frequently shows itself in large quantities in the blood, and is deposited by it in the tissues and fluids, saturating the bones, teeth, cartilages, ligaments, fibrous tissues (being especially evident in the sclerotic coat of the eye, and in the skin), showing itself also in the nerves, the crystalline lens, and the vitreous humour, and more or less tinging all the secretions and exudations into which the fluid of the blood passes,—yet this may fairly be attributed, as we shall presently see, to the re-absorption of the pigment subsequently to its elimination by the liver (§ 71). And looking to the general physiological relations of this organ, hereafter to be pointed out, we may surmise without improbability, that it is by its agency that the transformation is effected, and that the bile-pigments do not pre-exist *as such* in the blood.

71. With regard to the source of the various components of the Biliary excretion which have been now described, our information is much less precise than it is with respect to the principal excretory matters of the Urine. This arises, not merely from the difficulties already adverted-to as attending the chemical determination of the true constituents of Bile; but also from the fact that the detection of their presence in the blood by no means implies their pre-existence in the circulating fluid. For, as we shall hereafter see (CHAP. VII.), there is strong reason to believe that a considerable proportion of the solid matters of the bile, which are poured into the upper part of the intestinal tube, are normally re-absorbed, and again introduced into the current of the circulation, before reaching the outlet; and it is quite certain that such re-absorption may take place in cases of

obstruction in the biliary ducts, when the bile is secreted, but cannot find its way into the alimentary canal. Hence, neither the detection of cholic acid in the blood by Pettenkofer's test,—which has been occasionally accomplished, even in cases of disease in which the liver did not seem implicated, though never in perfect health,—nor its detection in the urine or in various fluids exuded from the blood, afford the least evidence that it was pre-formed there; any more, indeed, than does the accumulation of the colouring matter which makes its presence so obvious in jaundice. Of that evidence which is furnished in the case of the urine, by the detection of some of its characteristic components in the tissues which undergo most rapid disintegration, we have here a most complete deficiency; for no trace of the biliary acids has yet been found in the tissues, except under circumstances which justify the belief that these substances were deposited there. The only distinct indication yet obtained, that the characteristic components of bile are pre-formed in the blood (Cholesterine being scarcely to be reckoned as such), is afforded by the experiments of Kunde, one of the pupils of Lehmann; who demonstrated, by Pettenkofer's test, the presence of biliary matters in the blood of frogs whose livers had been extirpated. On the other hand, there is much that indicates, if it does not prove, that the function of the liver is not the mere selection and elimination of the elements of bile from the blood; but that it exercises a most important transforming power, both over the constituents of the blood, and over those of the bile. Of the evidence which has been lately adduced in proof of the first of these positions, some notice has already been taken (§§ 40, 46); and that of the second will be more appropriately considered hereafter (CHAP. XII. SECT. 2). At present it will be sufficient to remark, that, whilst a chemical comparison of the elements of the Bile and Urine shows that each of these excretions is (so to speak) the complement of the other, and that the mass of the blood or of the solid tissues might resolve itself into these two sets of compounds (§ 91), various physiological and pathological phenomena seem to indicate, that the products of the metamorphosis of the tissues which afterwards become the components of bile, do not take the form of those components, until they have been acted-on by the liver, and reduced to a state comparatively innoxious. For whilst there is abundant evidence that the constituents of bile, both its resinous acids, and its colouring matter, may be re-absorbed without serious injury; and whilst there is strong reason to believe that, as regards the resinous acids, such re-absorption is habitual; there is adequate proof, on the other hand, that the retention within the circulating current of the matters from which bile is formed, owing to structural disease or functional inactivity of the liver, is attended with the most serious consequences, and will, if prolonged, induce a fatal result.—It is surmised by Lehmann, in consequence of the resemblance already pointed out between the cholic and oleic acids, that bile is partly formed from the fatty matters of the system; but there is no adequate proof of this; and as we have seen that fatty matters may themselves be formed by the metamorphosis of albuminous substances (§ 40), there seems no reason to dissent from the usually-received opinion, that the chief source of biliary matter is ultimately to be found in the disintegration of the azotized tissues.

### 6. *Inorganic Substances forming part of the Living Body, and contained in its Excretions.*

72. Although it might have been supposed that the Chemist would have had comparatively little difficulty in determining what are to be regarded as the Inorganic or Mineral constituents of the body, yet the attainment of a precise knowledge of them is attended with peculiar difficulties, arising out of the mode in which these constituents are blended with Organic compounds. The usual method of determining their presence, nature, and amount, has been to incinerate the dried tissue or the solid residue of the fluid, and to analyse the ash which remains; but this process, as Prof. Lehmann justly remarks, gives us no information with regard to the combinations in which the constituents of that ash occurred in the organic substance. Thus, to take a simple example, nothing can be certainly made out from it with regard to the presence of lactic acid, since all the lactates are reduced by incineration to carbonates; so again, from the presence of sulphates and phosphates in the ash, it cannot be determined whether the sulphuric and phosphoric acids pre-existed as such in the organic substance, or whether they were present as sulphur and phosphorus, which, having become oxidized during the incineration, have combined with alkaline or earthy bases previously combined with lactic or carbonic acid. Further, the carbon of the organic compound may produce important alterations, during its combustion, in the condition of the mineral salts; thus it will tend to reduce the sulphates to the condition of metallic sulphurets, and to volatilize a portion of the sulphur in the condition of sulphurous acid; and it will have a similar effect upon the phosphoric acid of the acid salts. So, again, common phosphate of soda, at a high temperature, removes a part of the base, not only from the carbonates but also from the sulphates of the alkalies, as well as from the metallic chlorides of the ash; so that not only does all the alkaline carbonate disappear from the ash, but a portion of the hydrochloric or sulphuric acid may also be lost. When we consider these and other facts in reference to the analysis of the ash, we shall readily accord with Prof. Lehmann's remark, "that most of these analyses should be used with great caution, and that physiological conclusions should not be too readily drawn from them." The new methods recently introduced by Prof. H. Rose have led that eminent analyst to the conclusion, that various compounds of potassium, sodium, calcium, iron, phosphorus, and sulphur exist pre-formed in organic substances in an unoxidized state, and take an important part in their metamorphoses; for he finds that in the carbonaceous residue left after the incineration of an animal or vegetable substance, there is always a certain quantity of alkaline and earthy salts which cannot be removed from it by the ordinary menstrua, and which must, therefore, exist in it in some peculiar state of combination. And it is a confirmation of this view, that the proportion of such mineral matters contained in blood, flesh, milk, and yolk-of-egg, amounts to as much as from one-third to one-half of the whole; whilst those of urine, in which there is independent reason to believe that nearly all the bases and radicals are oxidized, do not amount to 0·6 per cent.

73. In the following account of the mineral components of the body,

therefore, those only will be mentioned, whose presence in it has been clearly determined; and even these must be arranged in two categories, according as their presence is *essential* or *accidental.* For whilst there are certain substances, which are constantly met with in such large amount, and which so obviously fulfil important purposes in the economy, that they may be unhesitatingly ranked among the essential components of the body, there are others which, although very commonly present, are found in very small proportion, and under circumstances which lead to the belief that they neither take a share in the nutritive operations, nor discharge any mechanical function in the living body, but that they have been (so to speak) accidentally introduced from the food, and that they are retained merely through defect of the eliminating processes. The presence of such matters, therefore, is of comparatively little interest to the Physiologist; but it is of great importance to the Medical Jurist, who may be called upon to declare whether copper, lead, or arsenic, found in a dead body, can be justly regarded as a normal component of the tissues.—We shall first consider, then, those inorganic substances which are to be regarded as *essential* components of the Human fabric; and since no classification of them, in the present state of our knowledge, would be likely to have any permanent scientific value, we shall arrange them in the order of what appears to be their relative importance in the economy. From these we shall pass to the substances found in the excretions, one of whose constituents has been generated by the metamorphosis of alimentary matters. And lastly, we shall notice those substances which appear to be only *accidentally* present in the body.

74. First, in order of importance,—whether we look at the large proportion of the bulk of the fabric which is formed by it, to the influence which its presence exerts on the physical properties of the various tissues into which it enters, or to the number and variety of purposes to which it is subservient in the chemico-vital operations of the living body,—is unquestionably *Water.* The quantity of this liquid which may be evaporated from the body by complete desiccation, is, according to the recent experiments of Chevreul,* about *two-thirds* of its entire weight; and its predominance is by no means restricted to what are commonly accounted the "fluids" of the system, such as the Blood, Chyle, Lymph, &c; since, as the following Table will show,† it is contained in nearly as large an amount in several of the so-called "solid" tissues.

| | Per-centage of Solid Matter. | Specific Gravity. |
|---|---|---|
| Bone | 80 to 90 | 1200 to 1600 |
| Hair | 60 | 1300 |
| Cuticle | 50 | 1200 |
| Nerve | 43 | 1100 |
| Skin | 30 to 40 | 1100 |
| Fibrous Textures | 30 to 35 | 1080 to 1090 |
| Artery | 25 to 30 | 1070 |
| Cartilage, Muscle, Glands | 23 to 28 | 1055 to 1060 |
| Blood | 20 to 23 | 1050 to 1055 |
| Wall of Intestine | 18 | 1040 to 1050 |
| Brain | 16 to 20 | 1030 to 1045 |
| Fat | . . . | 942 |

* "Anatomie Général," par P. A. Béclard, 3ième Edit. 1851, p. 53.
† See Prof. Allen Thomson's "Outlines of Physiology," p. 130.

When we examine into the uses of this large proportion of Water, we find, in the first place, that it serves a purpose simply mechanical; imparting to the tissues that suppleness and extensibility which characterize them in their natural state, but which are completely removed by drying them. Thus a piece of tendon, when desiccated, shrinks into a firm and nearly inflexible rod, much resembling a piece of dried glue; yet, if macerated in water for a sufficient length of time, it recovers, by the absorption of liquid, its original pliancy. In like manner, a piece of the yellow fibrous tissue of the ligamentum nuchæ of a Sheep or Ox dries into a hard unyielding substance; yet if allowed to imbibe its original proportion of water, it recovers its peculiar elasticity. The tissues in which we find least water, are those whose functions are most purely *physical;* thus we see that Bone, whose sole office is to afford an inflexible support, contains no more than from 10 to 20 per cent of fluid, the principal part even of this belonging to the softer tissues immediately connected with its nutrition; so in the Cuticle and its appendages, whose purpose is merely protective, and which are partly desiccated by exposure to the air, the proportion of solid matter is at least half. On the other hand, the proportion of water in Muscle averages 75 per cent, and in the substance of the Brain it is no less than from 80 to 84 per cent; the last-named tissues being among those of which the *vital* endowments are the most remarkable, and being those (as will be seen hereafter) in which the most rapid nutritive changes take place during their state of vital activity.

75. But further, the presence of Water is essential to the performance of all those chemico-vital processes, by which the integrity of the living body is maintained; and a deficiency in the aqueous portion of the fluids soon manifests itself in a disturbance of these operations, even though the constitution of the solid tissues may have not yet been affected. As a general rule it may be stated, that no Chemical action takes place between solid substances, and that they require to be dissolved in water or some other menstruum, before they can be made to affect each other; and we find that this rule holds good constantly in the organized fabric, alike of Plants and of Animals. No alimentary material can be appropriated by the organism, save in the liquid form; and hence it is that Animals, whose food is solid, are endowed with a digestive apparatus for its reduction to the state in which it may be absorbed by the sanguiferous and lacteal vessels, which answer to the rootlets of Plants, this state being either one of complete solution, or of very minute division. No other liquid than Water can thus act as a solvent for the various articles of food introduced into the stomach. Again, it is Water which continues to form the solvent of the nutritive materials, after they have found their way into the current of the circulation, and have undergone that assimilating process which prepares them for being applied to the renovation of the solid tissues; and, of the "vital fluid" which courses in minute streams through nearly every part of the body, vivifying and renovating the tissues which it traverses, water constitutes as much as from 76 to 80 per cent. So, again, it is the Water of the blood, which not merely brings to the living tissues the materials of their development in a state ready for appropriation, but also takes up the products of their disintegration and decay, and conveys them, by a most complicated and wonderful system of sewerage, altogether out of the system.—It is not difficult to under-

stand, then, how seriously the chemico-vital operations of the body must be affected by a deficiency in the normal proportion of this liquid, more especially as some of the substances to be transported are of very difficult solubility; and we find that the demand for it, when it is withheld, soon becomes even more pressing than the demand for solid food. It is remarkable that there are many Plants and even Animals, which can be reduced to a state of complete inactivity by the desiccation of their tissues, without the absolute loss of their vitality; the usual condition of their bodies being recovered, and their vital powers being restored, when they have been allowed to imbibe an adequate supply of water.*

76. Of the *solid* inorganic components of the Human body, that which is of greatest importance in regard to its amount and to the mechanical purposes to which it is subservient, is *Phosphate of Lime*, or 'bone-earth;' and there is a strong probability that it is subservient also to very important purposes in the chemico-vital operations of the economy.† It is in the *Bones*, that this earthy salt (which has been recently determined to be composed of 3 equiv. Lime + 1 equiv. Phosphoric acid, and not, as Berzelius supposed, 8 equiv. Lime + 3 equiv. Phosphoric acid,) presents itself in the greatest abundance. In healthy bones, its proportion ranges from 48 to 59 per cent; being greatest, as Von Bibra has shown, in those bones which are most required to possess resisting power.‡ In the *Dentine* of teeth, its proportion rises to 66 per cent; and in the *Enamel* to nearly 90 per cent. It is remarkable that, in this last situation, it should present an almost crystalline mode of aggregation, whilst the Enamel is the hardest of all organic substances, being capable of striking fire with steel; and it seems scarcely possible to avoid tracing a connection between these two facts, more especially as phosphate of lime, in certain states of crystallization, forms one of the hardest of all mineral bodies. On the other hand, in bones which are undergoing softening from any form of disease, the proportion of phosphate of lime is diminished; and an artificial softening may be induced by restricting animals to food containing little or none of this salt. In regard to the mode in

* See the Author's "Principles of Physiology, General and Comparative," p. 39.

† "The constant occurrence of Phosphate of Lime in the histogenetic substances, and especially in the plastic fluids," remarks Prof. Lehmann, "as well as its deposition in many pathologically-degenerated cells of the animal body, obviously strengthen the opinion that this substance plays an important part in the metamorphosis of the animal tissues, and especially in the formation and in the subsequent changes of animal cells." (Op. cit. p. 416.) This doctrine has been strongly advocated in a work entitled "Der Phosphorsäure Kalk in physiologischer und therapeutischer Beziehung" (Gottingen, 1850), by Dr. Beneke; who has further maintained, that in various diseases which are characterized by imperfect nutrition, the real source of the want of formative action lies in the deficiency of this substance, which is carried out of the system in abnormal quantity, whenever an excess of Oxalic acid is generated within it; in proof of which he alleges that great benefit is derived in such cases from the remedial administration of phosphate of lime, as well as from the prevention of the formation of oxalic acid, where this is possible. (See the "Proceedings of the Royal Society," June 20, 1850.)—It is remarkable that the glandular epithelium of the mantle of certain Bivalve Mollusks, which seems to be specially concerned in the formation of the shell, should be found to contain as much as 15 per cent of phosphate of lime, with only 3 per cent of the carbonate, the remainder of their solid components being made up of organic matter; yet the shell itself contains no more than a trace of the phosphate. (See C. Schmidt, "Zur vergleichenden Physiologie," pp. 58–60.)

‡ See his "Chemische Untersuchungen über die Knocken und Zähne des Menschen, und der Wirbelthiere," Schweinfurt, 1844.

which it is deposited, there is a strong probability (as already remarked, § 33,) that the earthy salt forms a definite chemical compound with the organic base. It is not only in the skeleton, however, that phosphate of lime presents itself; for it is a constituent of all the soft tissues of the body, being intimately united with the organic compounds which are their essential constituents. Thus the ash of Cartilage, amounting to more than 4 per cent, chiefly consists of bone-earth; and well-dried Muscular fibre contains about 1 per cent of this substance. It would almost seem, indeed, to be a necessary accompaniment to the protein-compounds, which are with difficulty freed from it completely (§§ 20, 22). As might be expected, therefore, it is met with in solution in all the animal fluids; both those which contain the nutritive materials, and those which are conveying out of the body the waste-matters of the system. In the former, it is no doubt held in solution by the protein-compounds; thus in Milk, we find it in intimate union with the casein, which has a special solvent power for bone-earth; and in Blood it is in like manner united with the albumen, and, in a less degree, with the fibrin. All fluids into which these substances pass, even in a state of incipient metamorphosis, —as the lymph of the lymphatics, the serous fluid which permeates the lacunæ of the tissues, the salivary, gastric, and pancreatic secretions, &c.— contain phosphate of lime as their accompaniment. On the other hand, it forms a considerable proportion of the inorganic constituents of the urine; and there its condition is entirely different, as it is completely dissociated from organic matter. Its solubility in that fluid seems due to the fact, that, although entirely insoluble in water, a small quantity of this salt is taken up by solutions of chloride of sodium or of hydrochlorate of ammonia, or by fluids charged with carbonic acid. And it is further remarkable, that lactic acid has a special solvent power for phosphate of lime; as much as $68\frac{1}{2}$ parts of this salt being dissolved by 100 parts of the anhydrous acid.—It is probable, as pointed out by Lehmann, that phosphate of lime may be formed within the body, by the union of phosphoric acid set free from the alkaline phosphates, or generated by the oxidation of phosphorus, with carbonate of lime contained in the food or water consumed; but there cannot be a doubt that the greater part of what is contained in the body, is introduced there ready formed. Of its abundance in the aliment of carnivorous animals, there is no need to say more; and it is present to a large extent in all the most nutritious articles of vegetable food, especially in the corn-grains.

77. Although the phosphate of lime is the principal solidifying ingredient of the Bones and Teeth of the higher animals, yet they also contain a considerable amount of the *Carbonate;* the proportion which the latter salt bears to the former being greater in young animals than in old.* Thus, according to Lehmann, the ratio of the carbonate to the phosphate is as 1 : 3·8 in the Bones of a new born child, as 1 : 5·9 in those of an adult male, and as 1 : 8·1 in those of an old male. So, according to Lassaigne, the proportion in the Teeth of a new born child is as 1 : 3·6, in those of a child of six years old as 1 : 5·3, in those of an adult as 1 : 6, and in those of an aged man as 1 : 6·6. In the *enamel* of human teeth,

* This statement is controverted by Von Bibra; but it is supported by the analyses of Lehmann and of many other chemists.

according to Von Bibra (Op. cit.), the proportion is as 1 : 20·5.—It is worthy of note that the massive skeletons of the inert Polypifera and Mollusca are consolidated by carbonate of lime, almost to the complete exclusion of the Phosphate; whilst the comparatively light and thin calcareous casing of the Crustacea, which, like the osseous skeleton of Vertebrata, serves for the attachment of the muscles that move the body, and therefore needs considerable strength in proportion to its substance, contains an appreciable amount of the phosphate. In phleboliths and other abnormal calcareous concretions, cretaceous tubercles, &c., the proportion of carbonate of lime is usually high. It is curious that carbonate of lime should normally present itself in a crystalline form, in a certain part of the human organism, namely, within the membranous lining of the vestibule of the ear, on the inner surface of which it is deposited, the crystals being sometimes contained within cells. They are very minute, so as even to exhibit the molecular movements characteristic of particles of very small dimensions; yet their crystalline form may be determined to be that of a prism derivable from the rhombohedron of calc-spar. Crystals of this nature occur much more frequently and abundantly among the lower animals, both in the organs of hearing and in other parts; thus among the Batrachia they are found in the membrane of the brain, and in that which lines the intervertebral foramina.—For the sources of carbonate of lime in the animal organism, it is not requisite to go far to seek; since almost all the water which is used as drink contains an appreciable portion of it, and in the waters that have percolated through calcareous soils, the amount of this salt is very considerable. Moreover, lime is taken-in by all herbivorous animals, in combination with vegetable acids; and these salts are converted into carbonates within the body; so that the carbonate of lime, if not converted into a sulphate, muriate, or phosphate, is excreted as such by the urine, in which it consequently appears occasionally in large quantities. This substance is probably held in solution in the animal fluids (as in ordinary spring water) by free carbonic acid; but the chloride of sodium and other alkaline salts which they contain, may exert an additional solvent power. —Of this substance it may be remarked, in conclusion, that there is no evidence of its subserviency to any other than a mechanical purpose within the living body.

78. With the foregoing calcareous salts, a small quantity of *Phosphate of Magnesia* is almost invariably associated. It is chiefly found in the bones; and its proportion is somewhat larger in the bones of herbivora than in those of carnivora, the largest proportion presenting itself in the teeth of Pachydermata. The ash of all the animal fluids and tissues contains a little phosphate of magnesia; and its presence is made known by the microscope in tissues in which putrefaction has actively commenced, these being everywhere studded with crystals of the 'triple phosphate' of ammonia and magnesia, a salt which is formed wherever phosphate of magnesia is dissolved in an ammoniacal liquid. Phosphate of magnesia is introduced into the body as a part of the ordinary food both of carnivorous and herbivorous animals; but it exists in much larger proportion in many vegetable substances, especially the seeds of the Cerealia, than it does in animal flesh; and as no more seems to be taken up than the system requires, the residue is carried off in the fæces, of whose ash

from $10\frac{1}{2}$ to 13 per cent. has been found to consist of phosphate of magnesia when a mixed diet was employed. It seems to be from the superfluity of this salt in their food, that the tendency to intestinal concretions arises in many herbivorous animals; those which are common in the horse, for example, consisting almost entirely of the triple phosphate, with fragments of straw, &c. The proportion of this salt which is absorbed, and which is embodied in the various tissues, seems normally to enter the urine when set free by their disintegration, and to be thus carried out of the body, at a rate corresponding to that of its introduction. If, however, free ammonia should be generated, either by decomposition of the urine, or by a state of incipient putrescence of the solids or fluids of the body, the triple phosphate is produced; and thus it is that it is often found in considerable amount in the urine, and that it presents itself in the fæcal evacuations in cases of typhoid fever. That it is a real excretion in the latter case, is sufficiently obvious from the fact that it cannot have been furnished by the food; and it is interesting to observe that its crystals are found thickly studding the ulcerated patches of intestinal glandulæ, which are probably the seat of their elimination. —There is no reason to think that the function of phosphate of magnesia in the system is less mechanical than that of carbonate of lime.

79. A minute proportion of *Fluoride of Calcium* has been so constantly found in the bones, that it may be considered as one of their ordinary components; how far, however, its presence is to be regarded as essential, or how far it depends upon the combination of this with other calcareous salts contained in the food, has not yet been determined. That it is specially attracted by osseous tissue, even when this is no longer alive, appears from the fact that fossil bones are often found to contain it in extraordinary amount, no less than 15 or 16 per cent being occasionally discovered in them; and this can scarcely have been derived from any other source, than a percolation of water charged with fluoride of calcium through the strata in which the bones were imbedded. It would seem, moreover, that the teeth, and especially the enamel, contain a much larger proportion of this substance than does any other living texture; thus Berzelius found 2·1 per cent of fluoride of calcium in the dentine, and 3·2 per cent in the enamel, of a human tooth. It is obvious that this compound must be derived from the solid or liquid aliment introduced into the system, and must be absorbed into the blood; and there is experimental proof that such is the case. Fluoride of calcium may be detected in many mineral waters, and is soluble, according to the experiments of Dr. G. Wilson,* in about 28,000 times its weight of water; and it is contained in the ashes of plants growing on micaceous soils. The same experimenter appears clearly to have determined its presence in Blood and in Milk, although he has not made a quantitative appreciation of it; and we may fairly expect that it might be detected in the Urine, if a sufficiently large amount were examined, this being the channel by which it would probably find its way out of the body.†

* Reports of British Association for 1850, pp. 67, 68.

† It is right here to mention, that although the presence of fluoride of calcium in the animal body has been very generally admitted, a doubt has been thrown upon the validity of the proofs usually relied on. Dr. G. O. Rees states ("Guy's Hospital Reports," No. ix.) that he could not succeed in unequivocally detecting this salt in bone-ash, although as little as

80. Although *Silica* is one of the most important mineral ingredients of many Plants, and is also abundant in some of the lower forms of Animal structure, yet it is present to only a very small extent in the Human organism, the sole tissue of which it seems to be a normal constituent being the Hair.* According to the analysis of Laer and Gorup-Besanez, about 0·22 per cent of silica is to be found in the ordinary brown hair of man; the ashes of which contain nearly 13·9 of this earth. It has been discovered in the blood of Man by Millon, and in that of the Ox by Weber, in both cases, however, in a quantity not exceeding 0·20 per cent of the ash; in the ash of birds' blood, on the other hand, its proportion is about five times as great, as might be expected from the larger demand for it in their organisms. Silica has been detected also in the bile and urine, and is obviously carried out of the system through these channels; what is found in the solid excrements has obviously been derived directly from the food. It is in the seed-coats of many seeds, especially those of the Monocotyledonous division, that the chief source of the silica introduced into the bodies of animals is to be found; and hence it is that the feathers of granivorous birds present a much larger proportion of silica than any others, and that granivorous quadrupeds are peculiarly subject to intestinal concretions including a large quantity of silica.

81. Among those inorganic components of the Human body, whose function is rather chemical than mechanical, we may first notice *Hydrochloric acid*, which may be regarded as an occasional, if not a constant component of the gastric fluid.† Both lactic and hydrochloric acids have a powerful action on albuminous substances; and there is reason to think that the acid reaction and solvent powers of the gastric fluid may be due to either one or the other. In the gastric fluid of Man, however, it seems certain (as will be shown hereafter, CHAP. VII.) that free hydrochloric acid normally exists, in such a proportion as to render it efficient as the solvent.

82. Of all the mineral constituents of the Human organism, there is none more important in a chemical point of view than *Chloride of Sodium*. This substance occurs in nearly every part of the body, both solid and fluid, in close and intimate relation with the organic compounds, whose chemical and physical properties are materially influenced

0·3 gr. added to 100 grains of bone-ash produced unequivocal corrosion of glass; and he is disposed to attribute the very different results obtained by other Chemists, to the power of *phosphoric* acid to corrode glass of inferior quality.—It may be, however, that the presence of this salt is purely accidental, depending upon an impregnation of the waters of the neighbourhood, and upon its reception into plants growing under circumstances in which it is abundantly supplied. If this be the case, it might be met with in considerable amount in some bones, and be entirely wanting in others.

* It is interesting to remark that Gorup-Besanez has found Silica to be a uniform component of the feathers of Birds; of the *ashes* of which it constitutes from 6·9 to as much as 65 per cent. Moreover, the silica presents itself in much larger amount in the feathers of adult birds than in those of the young, only traces of it being found in newly-grown feathers; and further, it is in the feathers of the wings, in which the greatest rigidity is required, that the largest amount of silica is contained.

† This acid can always be obtained from gastric fluid by distillation. It has been found, however, that lactic acid, which is also present in the stomach (§ 49), has the power of decomposing chloride of sodium, and of setting-free hydrochloric acid, by the aid of heat; but whether it ordinarily does this at the temperature of the stomach, is doubtful. Even during evaporation *in vacuo*, lactic acid will decompose chloride of calcium, and will thus disengage hydrochloric acid.

by it:—thus Albumen partly owes its solubility to this salt, and the differences which it presents in coagulating are in great degree dependent upon the quantity of it that is present; pure Casein, which is otherwise insoluble, is also dissolved by common salt; and if salt be added in increased proportion, it has the power of impeding the coagulation of the Fibrin of the blood. Moreover, this substance is not only uniformly present, but exists in nearly definite and constant proportions, in the several tissues and fluids; and the existence of a provision for the limitation of the quantity retained in the system, renders these proportions but little liable to be affected, in the way of excess at least, by the quantity of salt which the food may contain. Thus Lehmann found that whilst his own blood in a normal state contained 4·14 parts of chloride of sodium in 1000, this proportion was only increased to 4·15 after the use of very salt food which caused intense thirst, and only rose to 4·18 when two ounces of salt had been taken an hour before, and two quarts of water had been drunk in the interval. The quantity of salt in the blood in different diseases, however, is liable to great variation; and there can be little doubt that this variation is intimately connected (though whether in the relation of cause, or in that of effect, we are scarcely yet entitled to surmise) with the histological and other transformations of the components of the blood.* The proportion of chloride of sodium differs greatly in the several tissues, and also at different periods of the development of the same tissue. Thus in Muscle, according to Enderlin, 100 parts of the ash left after incineration of ox-flesh yielded nearly 46 per cent of the chlorides of sodium and potassium; which, as this ash constitutes 4·23 per cent of the dried flesh, would give 1·94 as the proportion of chloride of sodium in 100 parts of the latter; and reckoning this dried residue to constitute 23 per cent of the whole substance of the muscle (the remaining 77 parts being water), the proportion of chloride of sodium in the latter will be 0·44,—these figures, as will be presently seen, bearing a remarkably close correspondence to those which represent the proportion of chloride of sodium in the ash, solid residue, and entire mass, of the Blood. Next to muscle, the largest per-centage of chloride of sodium seems to be contained in Cartilage; and this especially in the temporary cartilages of the fœtus, the proportion diminishing as the phosphate of lime is deposited. The per-centage of chloride of sodium contained in the ash of the costal cartilage of an adult has been stated at 8·2, and in the laryngeal cartilage at 11·2; but as the ash does not constitute above 3·4 per cent of the entire substance, the per-centage of chloride of sodium in the latter is at most 0·38 of the whole, or less than that of blood and muscle. In Bone, only from 0·7 to 1·5 per cent could be extracted from the ash.—Besides the important uses of common salt in the Blood which have been already adverted to, it serves the important purpose of furnishing the hydrochloric acid required (by many animals at least) for the gastric secretion (§ 81); and it also furnishes the soda-base for the alkaline phosphate, whose presence in the blood appears to serve a most important purpose in the respiratory process (§ 84). Moreover, there is reason to think, from the experiments of Boussingault upon animals, as well as from other considerations, that the presence of salt in

* The special influence of the saline constituents of the Blood upon its red corpuscles, will be noticed hereafter (§ 139).

the blood and excreted fluids facilitates the deportation of excrementitious substances from the body.—The proportion in which it occurs in the principal animal fluids is represented by the following table, constructed by Prof. Lehmann chiefly from his own analyses.

Per-centage of Chloride of Sodium in various Animal fluids, their Solid Residue, and their Ash.

| | Liquid. | Solid Residue. | Ash. |
|---|---|---|---|
| Human Blood . . | 0·421 | 1·931 | 57·641 |
| Blood of Horse . . | 0·510 | 2·750 | 67·105 |
| Chyle . . . | 0·531 | 8·313 | 67·884 |
| Lymph (Nasse) . . | 0·412 | 8·246 | 72·902 |
| Serum of the blood (Nasse) | 0·405 | 5·200 | 59·090 |
| Blood of the cat (Nasse) . | 0·537 | 2·826 | 67·128 |
| Chyle (Nasse) . . | 0·710 | 7·529 | 62·286 |
| Human Milk . . | 0·087 | 0·726 | 33·089 |
| Saliva . . . | 0·153 | 12·988 | 62·195 |
| Gastric Juice of Dog . | 0·126 | 12·753 | 42·089 |
| Human Bile . . | 0·364 | 3·353 | 30·464 |
| Mucus (Nasse) . . | 0·583 | 13·100 | 70·000 |
| Serum of pus (Nasse) . | 1·260 | 11·454 | 72·330 |

The quantity of chloride of sodium contained in the Urine is liable to very great variations, being greatly augmented when an excess of salt has been ingested either in food or in water; and it is obvious that it is one of the offices of the kidney to filter off, so to speak, the superfluity of this substance from the blood. Chloride of sodium finds its way into the system, as a constituent of almost all articles both of vegetable and animal diet; it is also contained, though in small proportion, in most of the water which is used as drink; and by most races of man, it is used in considerable amount as a condiment. It seems probable, however, that the quantity which is really required is usually supplied by the ordinary diet; and there are numerous tribes which subsist in health and vigour without any additional source of it. Probably the inhabitants of inland countries may stand in greater need of salt, than the dwellers on the sea-board; since the plants grown in the latter situation contain a much larger amount of this saline derived from the atmosphere, than do those raised at a great distance from the ocean.

83. That a small quantity of the *Alkaline Carbonates* (especially of carbonate of soda) exists in ordinary Blood, though its presence was denied by Enderlin, is now generally admitted by Chemists. Lehmann states the proportion, as the mean of ten analyses of ox-blood, at 0·16 per cent. Since free carbonic acid is undoubtedly present both in venous and arterial blood, it has been maintained that its soda must be in the condition of a bicarbonate, since the ordinary carbonate of soda cannot remain as such in the presence of a free acid; but the soda-salt, whatever be its nature, is probably united so intimately with the protein-compounds, that its ordinary modes of combination are greatly modified. The carbonate and bicarbonate of soda (particularly the latter), have a special power of rendering Albumen soluble; and their presence in large quantity has the effect of impeding or altogether preventing the coagulation of the Fibrin, apparently through their power of chemically dissolving it.—The alkaline carbonates in the blood are probably for the most part

not introduced as such, but result from the decomposition of the lactates (§ 49) and of other salts formed by organic acids, a considerable amount of which must be ingested in the food of herbivorous animals. And one, at least, of their functions within the system, is to supply a base for the acids which are generated within it; these acids being produced (as in the case of phosphoric and sulphuric acids) during the disintegration of the tissues, and forming, with bases, neutral salts which are speedily eliminated from the system by the kidneys; or (as in the case of lactic acid) being developed by the metamorphosis of compounds which may have never formed part of the living tissues, and being only united temporarily with the base, to be reduced by the respiratory process, leaving the base in its original state of combination with carbonic acid. —The following, according to Prof. Liebig, are among the important purposes which are served by the alkalinity of the Blood. By its means, the chief constituents of the blood are kept in their fluid state; the extreme facility with which the blood moves through the minutest vessels, is due to the small degree of permeability of the walls of these vessels for the alkaline fluid. The free alkali acts as a resistance to many causes, which, in the absence of the alkali, would coagulate the albumen. The more alkali the blood contains, the higher is the temperature at which its albumen coagulates; and with a certain amount of alkali, the blood is no longer coagulated by heat at all. On the alkali depends a remarkable property of the blood, that of dissolving the oxides of iron, which are ingredients of the colouring matters of the blood, as well as other metallic oxides, so as to form perfectly transparent solutions. The free alkali serves also to promote the combustion of organic compounds, which in its presence acquire a power of combining with oxygen that they do not possess alone at ordinary temperatures; thus milk-sugar and grape-sugar, in presence of a free alkali, and with the aid of a gentle heat, deprive even metallic oxides of their oxygen. Further, it is by the alkalinity of the blood, that the metamorphosis of the malic, citric, tartaric, and other organic acids used as food, is promoted; and the same influence is exerted even over uric acid, which, when introduced into the system from without, is speedily resolved into urea and oxalic acid. If on the other hand, there be not an adequate supply of alkali in the blood, some of the vegetable acids (such as the gallic and tartaric) pass through it unchanged, and make their appearance in the urine; this being especially the case in carnivorous animals, whose blood (according to Prof. Liebig) contains more of the alkaline phosphates, and less of the carbonates, than that of herbivorous or omnivorous animals.* It was at one time maintained by Prof. Liebig, that the presence of carbonate of soda in the serum of the blood promotes the absorption of carbonic acid by the circulating fluid, this being displaced by oxygen in the lungs. He has latterly urged, however, that this action must be very insignificant, in comparison with that which is performed by phosphate of soda.†

84. The ordinary analyses of the blood and of other fluids of the living body, indicate the presence of a considerable amount of the *Alkaline*

* See Prof. Liebig's "Familiar Letters on Chemistry," letter xxviii; and his "Researches on the Chemistry of Food," pp. 93 *et seq.*

† See his "Researches on the Chemistry of Food," pp. 113–6.

*Phosphates*, soda being the predominating base; and much ingenious speculation has been put forth concerning their special uses in promoting the metamorphoses of tissue, arising out of the remarkable variety in the combining proportions of phosphoric acid and its bases. But it has been rendered doubtful, to say the least, by the recent analyses of Rose, whether the phosphates do exist *as such* in the blood, &c., and whether they are not rather formed during the incinerating process, by the oxidation of phosphorus, and the combination of the phosphoric acid thus formed with the alkaline bases previously combined with carbonic or with organic acids. Moreover, as it appears from the researches of Prof. Liebig just cited, that the relative amount of the alkaline phosphates and carbonates in the blood of different animals, is subject to great variation in accordance with the nature of their food (the former being in largest proportion in the blood of carnivorous, and the latter in that of purely herbivorous animals), it may be suspected that substances, whose quantity seems to be so much a matter of indifference, must either be of secondary importance in the vital economy, or must be in some degree vicarious with each other. This last idea is perhaps the nearest to the truth; for according to Prof. Liebig, the alkalinity of the blood in carnivorous animals is due much rather to the presence of the basic phosphate of soda, than to that of the carbonate. Moreover, the remarkable power which the serum of the blood possesses for the absorption of carbonic acid (nearly twice its volume of that gas being taken up by it at the ordinary temperature, which is double the amount which water will absorb under the same circumstances), is mainly due to the presence of phosphate of soda; a solution of 1 part of which in 100 parts of water is found to take up twice as much carbonic acid as an equal bulk of water will absorb at the same temperature, two-thirds of this being readily yielded up when the liquid is agitated with air, or the atmospheric pressure is diminished. This property is not possessed by a solution of phosphate of potash; and the constant presence of a certain amount of phosphate of soda in the blood, even when none exists in the food, which is very significant of its importance in the economy, is explained by Prof. Liebig by the fact, that when phosphate of potash is brought in contact with chloride of sodium, a double decomposition takes place, of which phosphate of soda is one of the products, this remaining in the blood, whilst the potash-salt is appropriated by the muscular substance (§ 85).* The alkaline phosphates find their way very readily into the urine; and it will be shown hereafter that a temporary augmentation of their amount in that excretion is often traceable to an unusual disintegration of Nervous matter, setting free its excess of phosphorus in the state of phosphoric acid. Where the largest proportion of phosphorized aliment is taken, there will of course be the largest proportion of phosphatic salts in the urine; and thus it happens that the urine of carnivorous animals is much more strongly acidified than that of herbivorous, and that the urine of the latter is often alkaline from the abundance of bases and the deficiency of phosphoric acid.

85. Although Soda has been spoken of as the predominant base of the alkaline carbonates and phosphates, yet the presence of *Potash* in appreciable quantity must not be left out of view, more especially as this substance presents itself in *muscle* in so much larger a proportion, that its

* "Researches on the Chemistry of Food," pp. 104–118.

special relation to muscular tissue can scarcely be a matter of doubt. The following, according to Prof. Liebig,* are the relative amounts of Soda and Potash in the Blood and Muscle of five different animals, the Soda being reckoned at 100.

| | Potash in the Blood. | Potash in the Flesh. |
|---|---|---|
| Fowl | 40·8 | 384 |
| Ox | 5·9 | 279 |
| Horse | 9·5 | 285 |
| Fox | . . . | 214 |
| Pike | . . . | 497 |

How far these proportions are liable to be influenced by the nature of the food, and within what limits they are normally confined, has not yet been determined; and it is scarcely yet safe, therefore, to found any theory of disease upon a supposed excess or deficiency of the potash-base.†

86. Although *Ammonia* is found abundantly in excreted matters, and may be regarded as one of the ordinary products of the decomposition which is continually taking place in the living body, yet it cannot be properly said to be one of its constituents, since it is nowhere found either in the nutritive fluids or in the living solids, so long as they preserve their healthy state. Even in the Urine, when freshly secreted in the state of health, it is positively denied by Prof. Lehmann that Ammonia exists; the precipitate thrown down on the addition of bichloride of platinum (which was regarded by Heintz as indicating its presence) being really a potash-salt. When decomposition commences in the fluid, however, a large quantity of ammonia soon shows itself; as it does also in certain states of disease (CHAP. XII. SECT. 3). Ammonia seems to be a normal constituent of the cutaneous and pulmonary exhalations; being found in the sweat, especially that of the axillæ, and in the halitus of the breath.

87. That *Iron* is a normal constituent of the Human body, has been already pointed out in the account of Hæmatin (§ 31). It is not by any means confined, however, to the red corpuscles; for it exists, though in minute proportion, in the *liquor sanguinis* in which they float, and it is found also in various solid tissues. The per-centage which it forms of the entire ash is, according to Rose's method, in ox-blood 6·84, in milk 10·47, in yolk of egg 1·85, in white of egg 2·09, in horse-flesh 1·00, in bile 0·23, and in fæces 2·09. According to Von Laer, hair contains about 0·4 per cent of iron, which amounts to no less than from one-ninth to one-half of the entire ash. The presence of this substance in such large and constant amount, especially in the nutritive fluids, shows that it cannot be regarded as an accidental component; but it must be confessed that nothing definite can be predicated of its uses. These are no doubt specially connected with the function of the red-corpuscles, whatever this may prove to be; and it is an additional indication of the colouring-matter of the bile being derived from hæmatin (§ 70), to find that iron is readily detectable in the former substance. As almost every article of ordinary food, whether

* "Researches on the Chemistry of Food," p. 107.

† The experiments of Dr. Garrod have led him to the conclusion, that the proximate cause of Scurvy lies in the deficiency of potash in the blood; and that this disease may be successfully treated by the administration of alkaline medicines alone. (See his papers in the "Lancet" and in the "Edinb. Monthly Journal," for 1848). A much larger induction, however, is requisite for the establishment of this position.

animal or vegetable, contains iron, its presence in the system is easily accounted for. Under ordinary circumstances, this source will be quite adequate; but when there is a deficiency in the amount of the red corpuscles of the blood, and it is desirable to accelerate their production, the administration of iron in a separate form, especially in conjunction with a diet of which animal flesh constitutes a large part, usually promotes their development.

88. The foregoing constitute all the inorganic substances (in addition to the Sulphur and Phosphorus already spoken of in connection with the protein-compounds), which can be regarded as normal components of the tissues and nutritious fluids of the Human body. There are certain others, however, which ordinarily present themselves in the excretions, either as constituents of the food which are at once rejected, or as results of the chemical processes that take place within the system; and which, though occasionally to be detected in the blood, seem to be present there only as on the road to their outlets. In this light we are probably to regard the *Alkaline Sulphates*, which, although abundant in the urine, are rarely to be detected in the blood, milk, bile, &c., except by processes which will oxidize the sulphur they may contain, and which will consequently produce sulphates that did not exist there before. Even when sulphates are taken into the stomach, it appears that they are ordinarily converted, in part at least, into sulphurets, in the alimentary canal; this change being due, as the experiments of Lehmann have shown, to the decomposition which is going on in the organic matters in contact with the saline. Of that which does not undergo this conversion, a small quantity finds its way into the circulation, to be immediately eliminated by the kidneys; whilst the residue, if large doses have been given, passes off unchanged in the fæces. When no such extraneous source of the sulphates exists in the solids or liquids ingested, the quantity of them which is found in the urine may be considered as representing an equivalent amount of sulphur which has been introduced into the system in combination with the protein-compounds, and which has been set free and oxidized in the final metamorphosis of tissue. The proportion is higher when a strictly animal diet is employed, than when the diet is of the ordinary mixed character; and higher on a mixed, than on a purely vegetable diet. This is just what might be anticipated, from the larger proportion of the sulphurized compounds in animal flesh.—It appears scarcely requisite to mention *Carbonate of Magnesia* under this head; since, although it is very commonly found in the urine and in the urinary concretions of herbivorous animals, it is comparatively rare in Man. As the magnesia seems to be introduced in the state of phosphate, this carbonate is probably formed by double decomposition with some calcareous salt formed by an organic acid, the lime being converted into a phosphate, and the magnesia uniting with the organic acid, to be afterwards reduced to the state of carbonate.—Under this head may also be noticed the *Sulpho-cyanide of potassium* which is usually present in human Saliva, and which gives a blood-red colour to the per-salts of iron, that is liable to be confounded with that produced by morphia. As this substance occurs in extremely small quantity, and as it is frequently absent altogether without any concurrent deficiency in the digestive power, it cannot be regarded as an essential constituent of the Salivary secretion.

89. We have now, in the last place, to advert to the asserted presence of certain Metals, as normal or occasional constituents of the Human body. That which is of the most importance in a medico-legal point of view, is *Arsenic;* which was at one time maintained by Orfila to be constantly met with in bones. That this statement was erroneous, has been fully proved by subsequent researches;* and it may be confidently asserted that the presence of arsenic in the tissues can only be attributed to its introduction into the system in some special mode. Even when minute doses of arsenic are introduced into the body, as by the use of mineral waters, vinegar, &c., containing this substance, they are speedily eliminated from it by the urinary secretion; so that the metal does not accumulate in the tissues. It is only when introduced more rapidly than the system can carry it off, that it exhibits its deleterious effects upon the economy, and that it is detectable in the solid tissues. Thus Dr. Letheby has shown that poisonous doses of arsenic may be repeatedly administered to animals, without the usual injurious consequences, if diuretics be given at the same time so as to occasion an unusual activity in their elimination. When even a single dose has been administered, however, sufficiently potent to occasion death, arsenic may very frequently be detected in the liver and kidneys (the excreting organs towards which it is specially determined), and sometimes also in the heart, lungs, brain, and muscles.—The frequent presence of *Copper* in the liver of Man, and in the bile and biliary concretions, may now be regarded as a well-established fact in Animal Chemistry; but it is not hence to be concluded that this metal is a normal constituent of his body. On the contrary, there is valid reason to believe, that when introduced in small quantities, either by its presence in the food or drink ingested, or by the accidental contamination of these by the utensils employed in their preparation, copper is removed by the excretory apparatus, the liver affording the special channel for its elimination. It is interesting to remark that copper appears to be a normal constituent of the blood of some marine Invertebrated animals (both Molluscous and Articulated), where it seems to replace iron.†—The presence of *Lead* in the tissues and fluids of the Human body would seem to be far more frequent; yet it is not entitled to rank as a normal component of the organism. Lead is pre-eminently *cumulative* in its tendencies; that is, when it has been introduced into the circulation in small quantities, the excreting organs make little effort to remove it, and it is deposited in the tissues. Thus it happens that the habitual ingestion of even very minute quantities of this metal, will, if continued for a sufficient length of time, give rise at last to the most severe symptoms; and that the entire body seems to be then charged with the poison, which may especially fix, however, upon particular muscles, or groups of muscles, which it paralyzes, and in whose substance it is deposited in very sensible amount. In the treatment of such cases, it is a matter of the greatest importance to obtain the elimination

* See the Report on this subject, made by a Committee of the French Institute in 1841. The medical witness, however, who is called on to speak as to the presence of arsenic in the tissues, may expect to be severely questioned as to this point by an opposing counsel, and should be prepared with his negative evidence.

† It is affirmed by Millon, that copper may be detected in human blood; but his conclusions have been controverted by Melsens. See "Ann. de Chim. et de Phys.," 3ième sér. tom. xxiii. pp. 358–372.

of the poison through the excretory organs; and it does not appear that either the liver or the kidneys can be acted-on for this purpose so effectually as the *skin*, through which the lead may be drawn forth in large quantities by means of warm sulphurous baths.† That the kidneys, however, do serve as channels for its removal, is proved by the detection of lead in the urine, by hydrosulphate of ammonia; and it seems to be to its power of rendering lead soluble, and, at the same time, to its stimulation of the kidneys to increased action, so as to eliminate the soluble compound, that we are to attribute the good effects which have been obtained from the use of iodide of potassium in removing Lead from the system.

### 7. *General Summary.—Operation of Chemical Forces in the Living Body.*

90. We have now passed in review the chief among those components of the Human body,—whether presenting themselves in its nutritive fluids, in its solid tissues, or in its excretory products,—whose existence has been made definitely known by Chemists. It is by no means to be assumed that what has here been stated affords a complete list of the chemical components of this fabric; still less, that the account which has been given of the metamorphoses they undergo, is to be received in the light of a determinate scheme. We should, indeed, regard it as a mere sketch or outline, in which the broad features are conveyed with tolerable distinctness, but of which the details remain to be filled-in by careful study. And the greatest advantage which can be derived from this method of viewing the subject, consists in the more definite boundary we are enabled to draw between what is known and what is unknown, and again, between what rests on a fair basis of probability, and what has no better foundation than vague surmise. Moreover, there is an obvious advantage in combining the *chemical* and the *physiological* view of the facts in question. For the mere Chemist will not only be liable to continual error, when he attempts to reason as to what takes place in the *penetralia* of the living body from what he observes in his laboratory, without taking into account the difference in the conditions of the phenomena (of which kind of error some of the speculations of Prof. Liebig have afforded remarkable examples); but he will also be at a great disadvantage in the prosecution of his inquiries, for want of the guiding clue which Physiological knowledge alone can afford. On the other hand, the Physiologist cannot safely make a step in advance, when engaged in the study of the metamorphoses of the alimentary materials into the living solids, and of the subsequent reduction of the latter to the condition of excrementitious matters, without relying on those exact data which Chemical tests and analyses can alone supply; it being to these, in fact, that he owes whatever definite knowledge he possesses of the composition of these several bodies, with which it is of the most fundamental importance that he should be acquainted. Accordingly, all the most productive researches of recent times, in this department, have been the work of men, who have either combined within themselves these two kinds of knowledge, or who have brought them to bear upon one another from extraneous sources.

* See a highly interesting case of Chronic Lead Poisoning, in which this remedy was most effectually employed, in the "Dublin Quarterly Journal of Medical Science," vol. vii. p. 415.

91. The following Summary is intended to convey, within a narrow compass, the leading conclusions, in regard to the Chemistry of the living Body, to which the Chemico-physiological labours of recent times appear to point.

I. The organic materials indispensable for the *genesis* of Tissue, consist of *Albuminous* and *Fatty* compounds.—The former present themselves under various aspects, in the Vegetable as well as in the Animal kingdom, all being reducible, however, to the ordinary state of Albumen by the digestive process; and in their natural states of combination, they include most of the inorganic substances which are required in addition. There is no reason whatever to believe, that Albuminous compounds can be generated within the animal body, by the transformation of substances belonging to an entirely different type.—The latter are directly afforded by ordinary animal food, and by many kinds of vegetable productions; and it seems to be when they are thus supplied, that they are most readily made available in histogenesis. They may be produced within the body, however, by the metamorphosis of either Albuminous or Saccharine compounds.

II. The great mass of those tissues of the body which belong to the *cellular* type, is generated at the expense of Albuminous matter; fat-particles, however, being intimately blended with this in an early stage of their formation. Of this we have a notable example in the case of Muscular tissue; but the cell-walls of all other textures would be found, if they could be entirely freed from their contents, to have the same composition. Even if they be altogether *chemically* identical, however, the molecular condition of the particles composing the amorphous coagulum and the living cell must be entirely different; and the latter exhibits distinctive *vital* properties, in virtue of the organizing process to which its material has been subjected. Not merely the cell-walls, but the cell-contents of these tissues (with the exception of those concerned in the act of excretion), seem to be derived from the Albuminous or from the Fatty constituents of the blood: this seems clear, for example, in regard to the globulin and hæmatin of the red corpuscles of the blood, and the horny matter of the epidermis and its appendages, which must have their source in the former; and also with respect to the contents of the adipose and nervous vesicles, which must be drawn wholly or in part from the latter. Whether, in the construction of the tissues of this class, the Albumen of the blood may serve directly as the *pabulum* for the production of cells, or whether it must needs pass first through the condition of Fibrin, cannot be distinctly affirmed; there is no positive evidence in support of either proposition; but the probabilities appear to the Author on the whole to favour the former view.

III. The great mass of the gelatigenous tissues of the body, whose texture is *simply fibrous*, is also derived from the albuminous element of the Blood; but this passes through the intermediate condition of Fibrin, which may be regarded as a substance endowed with the power of self-development into a low form of organized structure, and therefore as having already undergone a vitalizing influence. There is no sufficient reason to believe, that Gelatin employed as food can ever be applied even to this purpose in the body; since all that we know of the *genesis* of the simple fibrous tissues, indicates that in assuming their characteristic struc-

ture, they pass through gradations similar to those which we witness in the production of the adventitious tissue of fibrinous exudations.

IV. When the death and disintegration of the tissues again bring their components under complete subjection to Chemical forces, an entirely different series of metamorphoses takes place, tending to degrade these components towards the condition of inorganic compounds. They would seem to resolve themselves into two classes of substances;—on the one hand, saccharine, oleaginous, and resinous matters, analogous to those of plants, in which carbon predominates;—on the other, a set of compounds peculiar to animals, of which nitrogen is the characteristic ingredient. From the albuminous constituent of muscle, for example, there is direct evidence that fat, sugar, and lactic acid may be generated on the one hand; on the other, creatine, and (probably through this creatine) urea with the rest of the highly-azotized components of the urinary excretion. The sugar generated by the agency of the liver, from the products of the waste or disintegration of the system that are contained in the blood, seems to be at once employed in supporting the combustive process by which the animal heat is maintained. The fat may be directly applied to the same purpose, or may be stored up in the cells of Adipose tissue for future use. The peculiar resinous acids of the bile, which are probably formed from the same source, appear to fulfil, in part at least, a similar destination, after having been made subservient to other purposes. The lactic acid, chiefly generated in the substance of the muscles (probably by the metamorphosis of a saccharine compound, which may be looked on as the immediate product of their disintegration), is in like manner destined to be carried off by the respiratory process, though a part of it may first be rendered subservient to the digestive operation. But if the respiratory process should not be sufficiently active to remove these highly-carbonized compounds from the blood, we may find the lactic and hippuric acids in the urine, with the addition of carbonaceous pigmentary matter. On the other hand, the highly-azotized substances are destined for immediate elimination by the kidneys; their presence in the current of the circulation being so hurtful, that even a small amount of accumulation might induce fatal results.

V. Besides the foregoing substances, there are doubtless others which have not been so carefully studied, and which are passed off by distinct channels. Thus, we have no precise knowledge of those products of disintegration which are thrown off by the skin; and the proper fæcal matter, which is undoubtedly derived from some excretion poured into the alimentary canal, rather than from putrescent changes in the residue of the substances which are passing through it, has not yet been made the subject of accurate examination.

VI. Where more alimentary matter is introduced into the blood than is required for the *genesis* of living tissue, this probably undergoes the same decomposing changes, as do the effete matters that are set free by the disintegration of the organized fabric. The saccharine and oleaginous matters are directly carried off by the combustive process, only that portion being applied to the production of adipose tissue, which may not be required for the maintenance of the temperature of the body; whilst the albuminous and gelatinous appear to be resolved into the two classes of compounds already indicated, part of which are eliminated by the liver

and lungs, the other part chiefly by the kidneys, but also by the skin and (its internal reflexion) the alimentary canal. It may here be mentioned, as an additional evidence of the production of sugar from albuminous compounds within the living body, that it is found in the milk of Carnivorous animals, which have been for some time restricted to a diet of animal flesh.*

Our data are at present far too imperfect to allow this series of metamorphoses to be definitely represented by the aid of formulæ; nevertheless there are certain general relations which have a real existence, and which may be appropriately indicated in this mode. The following are given by Prof. Liebig, (" Familiar Letters on Chemistry," p. 439,) as examples of the transformations which *may* occur; it is to be observed, however, that some of the formulæ which he employs (op. cit. p. 437), differ from those in common use.

1 equiv. of Albumen with 10 equiv. of Water, contains the elements of 2 equiv. of Glutin and 1 equiv. of Choleic (tauro-cholic) acid, thus—

| | C. | H. | N. | O. | S. | | C. | H. | N. | O. | S. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 Albumen = | 216 | 169 | 27 | 68 | 2 | | 164 | 134 | 26 | 64 | | = 2 Glutin. |
| 10 Water = | | 10 | | 10 | | = | 52 | 45 | 1 | 14 | 2 | = 1 Choleic acid. |
| | 216 | 179 | 27 | 78 | 2 | | 216 | 179 | 27 | 78 | 2 | |

1 equiv. of Fibrin of Blood with 8 equiv. of Water, contains the elements of 1 equiv. of Glutin and 1 equiv. of Albumen.

| | C. | H. | N. | O. | S. | | C. | H. | N. | O. | S. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 Fibrin = | 298 | 228 | 40 | 92 | 2 | | 216 | 169 | 27 | 68 | 2 | = 1 Albumen. |
| 8 Water = | | 8 | | 8 | | = | 82 | 67 | 13 | 32 | | = 1 Glutin. |
| | 298 | 236 | 40 | 100 | 2 | | 298 | 236 | 40 | 100 | 2 | |

1 equiv. of Casein with 10 equiv. of Oxygen, contains the elements of 1 equiv. of Albumen and 1 equiv. of Chondrin.

| | C. | H. | N. | O. | S. | | C. | H. | N. | O. | S. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 Casein = | 288 | 228 | 36 | 90 | 2 | | 216 | 169 | 27 | 68 | 2 | = 1 Albumen. |
| 10 Oxygen = | | | | 10 | | = | 72 | 59 | 9 | 32 | | = 1 Chondrin. |
| | 288 | 228 | 36 | 100 | 2 | | 288 | 228 | 36 | 100 | 2 | |

The three preceding formulæ represent such metamorphoses as may occur in the *genesis* of tissues; the following represent some of those which may take place in their *disintegration*, in which (it must be remembered) oxygen drawn from the air performs an important part.

1 equiv. of Albumen with 10 equiv. of Water and 56 equiv. of Oxygen, contains the elements of 1 equiv. of Choleic (tauro-cholic) acid, 2 equiv. of Cholic (glyco-cholic) acid, 12 equiv. of Urea, and 36 equiv. of Carbonic acid.

| | C. | H. | N. | O. | S. | | C. | H. | N. | O. | S. | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 Albumen = | 216 | 169 | 27 | 68 | 2 | | 52 | 45 | 1 | 14 | 2 | = 1 Choleic acid. |
| 10 Water = | | 10 | | 10 | | | 104 | 86 | 2 | 24 | | = 2 Cholic acid. |
| 56 Oxygen = | | | | 56 | | = | 24 | 48 | 24 | 24 | | = 12 Urea. |
| | | | | | | | 36 | | | 72 | | = 36 Carbonic acid. |
| | 216 | 179 | 27 | 134 | 2 | | 216 | 179 | 27 | 134 | 2 | |

1 equiv. of Glutin with 10 equiv. of Oxygen, contains the elements of 1 equiv. of Cholic (glyco-cholic) acid, 3 equiv. of Uric acid, and 12 equiv. of Water.

| | C. | H. | N. | O. | | C. | H. | N. | O. | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 Glutin = | 82 | 67 | 13 | 32 | | 52 | 43 | 1 | 12 | = 1 Cholic acid. |
| 10 Oxygen = | | | | 10 | = | 30 | 12 | 12 | 18 | = 3 Uric acid. |
| | | | | | | | 12 | | 12 | = 12 Water. |
| | 82 | 67 | 13 | 42 | | 82 | 67 | 13 | 42 | |

* This was at one time denied by Dumas; but the fact has been fully established by the researches of Bensch, who has also explained the reason of Dumas' failure to detect the presence of sugar. (See " Ann. der Chem. und Pharm." band lxi. p. 221).

1 equiv. of Chondrin contains the elements of one Cholic (glyco-cholic) acid, 2 Uric acid, and 8 Water.

| | C. | H. | N. | O. | | C. | H. | N. | O. | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 Chondrin = | 72 | 59 | 9 | 32 | = | 52 | 43 | 1 | 12 | = 1 Cholic acid. |
| | | | | | | 20 | 8 | 8 | 12 | = 2 Uric acid. |
| | | | | | | | 8 | | 8 | = 8 Water. |
| | | | | | | 72 | 59 | 9 | 32 | |

Now although it must be admitted that, by a dexterous management of formulæ, almost any kind of transformation may be effected *on paper*, yet the above coincidences are so remarkable in themselves, and are so closely accordant with phenomena of whose occurrence we have independent evidence, that it seems hardly just to regard them as merely fortuitous.

VII. The Inorganic acids, bases, and saline compounds, which properly rank as constituents of the body, are for the most part applied to its construction in the forms in which they were introduced from the food; and they reappear under the same forms in the excretions. But new compounds are also produced during the progress of the metamorphic changes already referred to. Thus, a portion of the sulphur taken-in as a constituent of albuminous food, seems to be oxidized in the final disintegration of the tissues by which that albumen was appropriated, and is converted into sulphuric acid; a part, however, still remaining unoxidized, and passing off in that state, both by the bile and the urine. So, again, if phosphorus (as such) be a constituent of the protein-compounds, or be united with fatty matters, it must undergo a similar oxidation within the system; as it scarcely ever presents itself in the excretions under any other form than that of phosphoric acid. On the other hand, by the oxidation of various organic acids largely contained in vegetable food, their alkaline bases are reduced to the state of carbonates, so as to be ready to combine with any of the stronger acids that may be present in the system; and ammonia seems also to be generated *de novo*. Thus a supply of bases is prepared, ready to neutralize not merely the acids whose mode of production has just been described, but also the uric, hippuric, and lactic acids which are generated within the body, and which do not readily pass off from it except in combination with bases; and according as the proportion of these bases is equivalent to that of the acids, exceeds it, or is exceeded by it, will the urine be neutral, alkaline, or acid.—When mineral substances, whose presence is superfluous or noxious, are introduced into the body, an effort is usually made for their elimination, by some of the excretory organs; most commonly by the kidneys.

92. There is very strong evidence that, in all these transformations, Chemical forces are alone concerned; this evidence arising, on the one hand, from the nature of the changes themselves; and, on the other, from the certainty that such forces *must* be in operation, and that their effects will be modified by the peculiar conditions under which they are exerted. We have already seen that many of the changes taking place within the living body, can be precisely imitated out of it, by the use of means whose actual operation is of the same kind, though the *modus operandi* may be very different. Of this a remarkable example is afforded by the process of *oxidation*, which is continually going on within the system, and which produces a most important influence on the condition of the products of its disintegration. When the Chemist desires to convert one organic compound into another by oxidation, he treats it with some substance (*e.g.*

nitric acid or peroxide of lead) which readily yields oxygen; whereas the Physiological method is altogether different, for the substance to be acted-on, being diffused through the circulating fluid, is exposed to the direct influence of the oxygen of the air, in a state of almost infinitely minute division, during the passage of that fluid through the multitudinous capillary channels of the lungs. Now of the efficacy of this state of subdivision, in bringing about changes which do not occur when the substances to whose attractive forces these are due are simply exposed to each other *en masse*, we have a very remarkable example in the fact, that iron, when reduced from the oxide to the metallic state by a current of hydrogen gas, and thus left as a very fine powder, becomes spontaneously ignited by exposure to common air, and oxidizes as rapidly as a piece of iron-wire would do when burned in pure oxygen or immersed in nitric acid. This point has scarcely been sufficiently attended to by Chemists, who have too readily satisfied themselves with accounting for such metamorphoses by laboratory-operations, without inquiring how far similar agencies could be at work within the body: and we shall hereafter find that this powerful oxidizing process is probably employed, not merely in the combustion of materials introduced into the body, or supplied from itself, for the maintenance of its heat; nor only, in addition, for the removal of some of the products of its own disintegration; but also for the decomposition and elimination of certain organic poisons, from which, when they have been introduced into the body from without, it is freed through this channel, as it is from many of those of a mineral nature through the kidneys.—Allusion has already been made, again, to the peculiar action of *ferments* (§ 19), which tends to produce new and simpler arrangements of the elements of organic compounds, such as no ordinary reagents could effect. And it has been also pointed out, that the very same substance in different stages of decomposition, may occasion the genesis of several different sets of new compounds, according to the state in which it may itself happen to be when employed for this purpose. Moreover it has been also seen, in how very marked a degree the condition and the metamorphoses of organic compounds are affected by the presence of very small quantities of inorganic substances; but whether their influence be that of ordinary chemical attraction, or that which has been termed "catalytic" power, cannot yet be positively stated.—It is to be remembered, moreover, that the circulating fluid, which is probably the seat of most of these metamorphoses, is itself in a state of constant change; that new components are continually being introduced, on the one hand from the alimentary materials, and on the other from the disintegration of the tissues; and that such a condition must be eminently favourable to the chemical metamorphosis of its organic constituents.—It may be remarked, moreover, that the mode in which *capillarity* is brought into action in the processes of nutrition, is likely to have an important influence in determining further chemical changes, in virtue of the galvanic action which may thus be set up; it having been shown by Becquerel, that if the bend of a syphon be filled with fine sand, and an acid be poured into one leg and an alkaline solution into the other, the chemical action which ensues at their point of meeting will give rise to a galvanic current between the contents of the two legs, when these are connected by a wire passing from one to the other through the open ends of the syphon. As the blood and the tissues

are continually acting chemically on one another through the permeable walls of the vessels, it is scarcely possible but that electric currents should be thus generated; and it seems very probable that these may perform an important part in the metamorphoses in question.

93. On the whole it may be confidently affirmed, that of the changes which have been described in the present chapter, there are none—save the production of Fibrin, whose peculiarly vital properties have been already dwelt on (§ 29),—which there is any adequate reason to attribute to other than Chemical agencies; for if all cannot yet be precisely imitated by laboratory-processes, this imitation has been successfully practised in the case of a large number of them; and the nature of the remainder is such, as leaves it by no means improbable that they too will be reduced to the same category. In treating of this subject, it would be very easy to obtain a temporary solution of all difficulties of this kind, by regarding every case not otherwise explicable as a manifestation of "vital force;" but such a method is altogether inconsistent with sound philosophy; and we have no right to call in the assistance of vital force on any other occasion, than when we witness phenomena which are not only inexplicable by, but altogether inconsistent with, the known operations of Physical and Chemical forces. Phenomena of this kind will hereafter come under our consideration; but none such (with the single exception just referred to) have yet fallen under our notice; the metamorphoses we have been considering being mere changes in composition, analogous to those which *have* been effected in the laboratory; and the elements alike of the original substances, and of the products of their changes, being held together by affinities in which Life has obviously no concern.—It is not here denied, however, that Vital Force has an influence upon the Chemical phenomena of the body; on the contrary, much evidence will be hereafter given, that such an influence *is* exerted, especially through the nervous system. But this agency may be considered to operate, after the manner of Electricity or Heat, in modifying the play of ordinary Chemical attractions, rather than in substituting for them a new set of "vital affinities."

94. The highest estimate, however, that we seem justified in making, of the play of Chemical Affinities in the living body, is applicable only to those transformations, which, on the one hand, prepare the *pabulum* for that Organizing process, whereon is dependent the development of *vital* properties in substances that were previously inert; and which, on the other, minister to the application of the effete matters, resulting from the disintegration of tissues whose term of life is over, to purposes that are advantageous to the system in general, or are subservient to their removal in the most effective manner from the economy, to whose operations their continued presence would be prejudicial. Thus the reduction of all the protein-compounds to the condition of Albumen, in the digestive process, and the introduction of this substance into the blood in its soluble form, can be accounted nothing else than a purely chemical operation. The same may be said of the conversion of starch into sugar, and of sugar into fatty matter. It may be surmised, moreover, that the production of globulin and of hæmatin from albuminous material, may be due to chemical actions determined by the vital agency of the floating cells of the blood, in the manner indicated in the preceding paragraph. And the same may be true of the change of composition (if any difference really exists), which

is a part of the metamorphosis of albumen into fibrin; and of that still more decided change which subsequently takes place, when the fibrous tissues are converted, in the act of formation, into the substance which yields gelatin. For, as already pointed out, although the Chemist has not yet succeeded in imitating this metamorphosis, yet there are circumstances which indicate that such a fundamental relation exists between the protein-compounds and gelatin, as leaves no right to assume that any other than chemical forces are concerned in it.

95. But with the changes directly concerned in the *development of living tissue*, Chemistry would seem to have nothing whatever to do. The substance of Muscle, for example, is *chemically* the same with the Albumen of the blood; and the whole difference between the organized structure possessed by the former and the amorphous coagulum formed by the latter, between the marvellous activity of the one and the passive inertness of the other, must be attributed to Vital force alone. Now it is one of the chief peculiarities of this Vital force, that it is able, so long as it is capable of being fully exerted, to resist and keep at bay the influence of those Chemical and Physical forces, which would tend, were it not for this property of the living substance, to effect its speedy disintegration and decay. Of this we have a most characteristic and apposite example, in the case of a seed that has been brought to the surface of the soil, after having been buried for a long lapse of years or centuries in the earth. Whilst it remained in complete seclusion from moisture and oxygen, and was kept at a low temperature, no appreciable alteration took place in it; but so soon as it is exposed to warmth, and to the contact of air and water, it *must* begin to change,—its passive existence giving place to a state either of growth or of decay, according as it has retained, or has lost, its vital properties. For the very agents which are most effectual in stimulating it to vital activity, and which afford the conditions, dynamical and material, whereby the seed developes itself into the plant, are those which, if the seed be no longer capable of germination, most favour its decay, reducing its organic components back to the condition of inorganic compounds.

96. Immediately, however, that we pass the confines of Life, we re-enter the domain of Chemistry; for so soon as the vital activity of the living tissues has ceased, their materials again become entirely subject to Chemical forces; and all the metamorphoses which we have been occupied in tracing out,—tending, as they do, to reduce the organic compounds with which they commence, lower and lower in the scale, until these are restored to the forms of simple binary composition from which their elements were at first derived,—can scarcely be regarded in any other light than as the result of ordinary Chemical agencies. Thus, then, according to the view here advocated, the Life of each part is dependent upon Chemical operations, in so far as it is by these that its nutrient materials are prepared, and the products of its decomposition are carried away; but the application which it makes of such materials to the production of new organized tissue, and the various actions which that tissue then exerts in virtue of its organization, are not only incapable of being explained on Chemical principles, but often take place in direct antagonism to Chemical forces.*

* It has seemed advisable to attempt thus to mark out the operation of Chemical Forces in the living body, since the prevalent notions on this subject appear to the Author either erro-

# CHAPTER III.

## OF THE STRUCTURAL ELEMENTS OF THE HUMAN BODY, AND THE VITAL ACTIONS WHICH THEY EXHIBIT.

97. It may be stated as one of the most general facts in Physiology, that *Vital force* can only manifest itself through that peculiar arrangement of matter, which is distinguished as *organized structure;** since this alone affords that assemblage of *material conditions*, which is required to concur with the *dynamical agency* that is the active principle of the whole, for the production of the phenomena of Life. (See Introduction, p. 3.) But of such organized structure, there are a great many varieties, even within the single organism of Man. Thus it has been customary to reckon as the distinct structural components, or *Elementary Tissues* of which his fabric is composed, Bones, Teeth, and Cartilages, which form its solid framework, with the Ligaments which unite these to each other, and the Tendons which communicate motion to them from the muscles;—the Skin (with its appendages) which envelopes the exterior of the body, the Mucous Membranes which are prolonged from this into all the cavities that are connected with its surface, and the Serous Membranes which line the shut sacs;—the Blood-vessels and Absorbents, which serve for the distribution of the nutritious fluids, and the Glands which eliminate various substances from these;—the Muscles which communicate motion to the osseous framework, or to the contents of the canals and tubules that convey alimentary and other substances through the system, and the Nerves which excite the Muscles to contraction and also serve as the instruments for the reception of sensations and for the operations of the mind,—and finally, the Areolar tissue which serves to connect together the preceding, and the Adipose which is commonly diffused, more or less universally, through this, but sometimes forms masses of its own;—each of these having a structure and a mode of vital action in some degree peculiar to itself; and being hence considered as possessing distinctive vital endowments. In attempting, therefore, to analyze the varied and complex phenomena which make up the physiological history of Man, there is an obvious advantage in first making ourselves acquainted with these elementary components of his corporeal structure, and with the several forms of vital activity to which they minister. But, although, by so doing, we might seem to have commenced with the very foundations of Physiological

neous or vague. The accumulating evidence of the purely chemical nature of many of those changes of composition, which were formerly set down as the results of "vital affinity," has led many Chemists to the idea, that the *whole series* of Vital operations is to be explained upon Chemical principles; and the notion of Vital force has been set aside as a physiological fiction, for which there is no longer any pretence. Feeling satisfied, however, that *Vital force* has as certain an existence, and as definite a sphere of operation, as Chemical Affinity, the Author will make it his endeavour, in this Treatise, so to analyse the phenomena of the living body, as to trace the respective limits of the operation of each of these powers.

* For the distinctive characters of Organized Structures in general, see the Author's "Principles of Physiology, General and Comparative," chap. ii.

Science, yet such is not really the case; for before considering what are the peculiar distinctions in structural arrangement and in vital properties, which these tissues severally exhibit, we should inquire what they all have in common, and should seek to determine whether there be any fundamental relation between their respective types of organization and modes of vital activity, which is capable of being embodied in a general expression. And this inquiry has a value at the present time, to which it could never before lay claim; since, on the one hand, the microscopic examination of the Elementary Tissues, not only in their complete state, but also in their various phases of development, has shown that they have far more of similarity in intimate structure, as well as a closer community of origin, than could have been even suspected without such scrutiny; whilst, on the other, the clearer apprehension to which we have been led by the progress of Physical Philosophy,* in regard to the relations of different modes of Dynamical agency, seems to render it possible to attain to a far more definite and comprehensive view than was previously within our reach, in regard to the nature of Vital Force, and the conditions of its operation. Of the existence of this force, we have just as much evidence in the phenomena exhibited by living beings, as we have of the force of Gravitation in determining the movements of the heavenly bodies, or of that of Chemical Affinity in producing changes of combination among the elements of our own planet. But the peculiar complexity of the circumstances under which it operates, and the co-operation of Chemical and Physical agencies in many of the phenomena which essentially depend upon it, frequently obstruct the recognition of its acts, and constitute an additional reason for studying these under their simplest forms.

### 1. *Of the Elementary Forms of Organic Structure, and their Modes of Vital Activity.*

98. All the Elementary Tissues seem reducible by Microscopic analysis, to three primitive forms;—namely, Cells, Fibres, and Membranes. Of these it is obvious that *Cells* are the most essential; since in the entire Vegetable kingdom, as well as in the lowest tribes of Animals, the whole fabric is composed of cells and their derivatives; and there is a period in the history of even the Human organism, when neither of the other elements exists. We shall find, moreover, that it is by cells and their derivatives, that all the proper *vital* actions of the body are performed. To these elements, however, *Fibres* † are added in the bodies of the higher Animals; for the sole purpose, apparently, of conferring upon their parts that freedom of movement, which is essential to the conditions of Animal existence. There is every reason to believe that their function is purely *physical;* being nothing else than the resistance to tension (with or without a certain degree of elasticity), of which advantage is taken in two principal modes; such fibres being used to bind together separate parts that are to have a certain range of motion one upon the other, and also to

* See especially Prof. Grove's Treatise on "The Correlation of the Physical Forces."

† This term is here used in the strict sense, as applicable to the solid and simple fibres of which Ligaments, Tendons, &c. are made up, and not to the (so-called) Muscular and Nervous fibres, which, as will hereafter appear, are really *tubes* consisting of elongated or coalesced cells.

communicate and apply mechanical power generated at some other and (it may be) distant point. The simple homogeneous *Membrane*, also, which is known as "primary" or "basement-membrane," must be considered as one of the less essential among the fundamental constituents of the Human organism; though its office is still of great importance. As regards the vital functions, simple membrane may be considered as entirely passive; but it serves the very important physical purpose of limiting and bounding the tissues of various organs, and of separating the various collections of fluid within the body, in such a manner as to prevent their too-ready admixture, whilst admitting a certain amount of transudation from one to the other.—We shall now consider each of these Elements in more detail.

99. *Of Cells, and Cell-Life.*—The Cells which are thus to be regarded as the fundamental components of the Animal body, differ in no important particular of structure or composition, from those of which the Vegetable fabric is made up; and their endowments also may be shown to be essentially similar, although by no means identical.*—The fully-formed cell (Fig. 4) is a membranous bag or vesicle, enclosing a cavity, which is occupied by some kind of liquid or solid substance. Its typical *form* may be considered as *globular* or *spheroidal;* but this is comparatively seldom exhibited, except in newly-generated cells; for it is usually more or less altered subsequently, by forces operating either within the cell or externally to it. Thus the cells of adipose tissue, which are usually spheroidal when lying separately in the midst of areolar tissue (Fig. 39), become *polyhedral* by mutual pressure when compacted into a mass (Fig. 146, *e, e*). Many kinds of cells have the form of *flattened discs;* these being sometimes regularly circular or elliptical, as the red corpuscles of the blood (Figs. 10 and 11), sometimes polygonal, as the pigment-cells of the choroid coat (Fig. 32) and some varieties of the pavement-epithelium (Fig. 12); but frequently of irregular outline, as is more commonly the case with the pavement-epithelium (Fig. 19) and with the cells composing the parenchyma of the liver (Fig. 134, B). This flattening proceeds so far in the cells of the epidermis, as to render them mere *scales* (Fig. 29, *a*). On the other hand, the originally-spheroidal cells may become elongated, instead of depressed; and may then assume either a very regular *prismatic* form with flattened polygonal extremities, as in some varieties of cylinder-epithelium, but especially in the enamel of teeth (Fig. 58); or these elongated cells may be more or less cylindrical with pointed extremities, thus becoming *fusiform* or spindle-shaped, as is well shown in the cells forming the shaft of the hair, but still better in those of which the 'smooth' or 'non-striated' muscular fibre is composed (Fig. 79). One of the most curious examples of change of form, however, is presented by those cells, which, while not departing from the spheroidal type, send out

FIG. 4.


Cells from chorda dorsalis of Lamprey:—*a, a*, their nuclei.

* See "Princ. of Gen. and Comp. Phys.," CHAP. IV.

*caudate* processes; and these, when they issue from the whole circumference of the cell, give to it a *stellate* character. Both caudate and stellate cells are found in the vesicular substance of the nervous tissue (Fig. 86), and in the pigment-cells of the lower animals (Fig. 66, *c*); and it is probable that the 'lacunæ' and 'canaliculi' of bone (Fig. 48) are stellate cells, and that it is also by the inosculation of the peripheral extensions of such cells, that the ultimate ramifications of capillary blood-vessels, absorbents, and nerves, are at first generated (Fig. 68).—The *size* of cells is not less variable than their forms. Thus even in the Human body, we find them ranging from 1-300th of an inch, which is the diameter of many fat-cells and nerve-vesicles, to about 1-3200th of an inch, which is the average diameter of the red blood-discs, and thence to as little as 1-10,000th or even 1-15,000th of an inch, which is the ordinary diameter of the fibrillæ of the 'striated' muscle, each of which, as will be shown hereafter, is a linear series of very minute cells (Fig. 74).—Either lying freely within the cavity of the cell, or, as more commonly happens, attached to some part of its walls, we usually find a body of a somewhat granular appearance, which is called a *nucleus* (Fig. 4, *a*). And thus, in examining into the structure and endowments of cells, we have to consider (1) the cell-wall, (2) the cell-contents, and (3) the nucleus.

100. *The Cell-wall*, in its primitive state, is an apparently-structureless or homogeneous membrane of extreme tenuity; resembling, in fact, the basement-membrane to be hereafter described. In composition it agrees uniformly (so far as is yet known) with the protein-compounds; and it is only when adventitious deposits have been made upon its interior, from the peculiar contents of the cell,—as in the case of the deposit of horny matter within the cells of the epidermic tissues,—that its character seems altered. This uniformity in the composition of the cell-wall is indicated, independently of other considerations, by the uniform action of acetic acid upon it; for except in the cases in which the original cell-walls are thickened by secondary deposit, this reagent renders them so transparent, that they become for the time almost invisible, though brought into view again on the addition of potash. It is one of the most remarkable peculiarities of this membrane, that whilst it keeps together the liquid contents of the cell, and can afford resistance to any ordinary mechanical force tending to their expulsion, it may still permit the most ready transudation of fluids, although not the slightest trace of pores for their passage through it can be seen with the highest magnifying powers. And thus, in the ordinary current of nutrition, fluids may pass from cell to cell, apparently by endosmotic action, with considerable rapidity, notwithstanding the presence of the intervening septa. There is no evidence that this membrane possesses any distinctly vital property; and its function appears essentially to consist in the *limitation* of the cell-contents, which are drawn together by other agency. For when we examine into the history of *cytogenesis*, or cell-formation, we shall find that when cells originate *de novo*, the cell-membrane is generated at a comparatively late stage, not making its appearance until the other components are already in existence (§106).

101. The *Cell-contents* are as varied in their composition, as the cell-walls are uniform. In the first place, they may be either solid or liquid. Of the solid, we have examples in the prismatic cells of the enamel of

teeth (Fig. 58), which are completely filled with mineral matter in a state of crystalline aggregation, just as are the prismatic cells which form the external layer of many bivalve shells.* So, again, the contents of the cells which constitute the horny layer of the epidermis and the substance of the nails (Fig. 33), become solid by the desiccation of the fluid in which the horny matter seems to have been originally dissolved. It is obvious, however, that no vital action can go on, in cells whose contents are of such a character; and we accordingly find that the tissues thus consolidated are completely thrown out of the current of change, and that their functions are purely physical,—that of the Epidermis and its horny appendages, as well as of Shell, being simply protective, and that of the Enamel of teeth being to resist pressure. The *liquid* cell-contents are extremely various; and it is, in fact, in their diversity, that the peculiarity of many tissues consists. Thus, as we shall hereafter see, all the glands are formed upon a plan essentially the same; and their different endowments are entirely due to the diverse properties of the cells of which they are essentially composed, one set filling themselves with the components of bile (Fig. 25), another with those of milk, another with sebaceous matter, whilst within another set are generated the moving particles characteristic of the seminal secretion (Plate I, Fig. 3). Again, we shall find one set of cells drawing fatty matter into their interior from the contents of the alimentary canal (Fig. 100), whilst another set, eliminating a similar substance from the blood, stores it up as a part of the bodily fabric (Fig. 39). And the colour which is characteristic of particular parts, as, for instance, the lining of the choroid coat of the eye, the mammary areola, the hair, and the entire epidermis of the dark races of mankind, the red corpuscles of the blood, and the vesicles of nervous matter, is due to the presence of pigmentary matter, either of a deep black, or of some lighter hue, which forms either a part or the whole of the contents of particular cells. These several sets of cells cannot be formed, therefore, unless that *pabulum* be supplied to them, which they require, not merely for the generation of their cell-wall, but also for the filling of their cavity with its characteristic contents; and we shall find that in some instances this pabulum appears itself to contain these peculiar substances already formed, whilst in others the cell seems to exercise a certain converting power, by which it produces them from some other compounds. Not unfrequently, the contents of the cells include a number of minute molecules; and these exhibit an active movement within the cell, especially when water is added, so as to dilute the fluid in which they are suspended. This movement, which is well seen in the interior of the colourless corpuscles of the blood, of the nerve-vesicles, of pus and mucus-corpuscles, of pigment-cells, and occasionally in cells of other kinds, is not to be regarded as having any dependence on vital forces; for it is nothing else than the "molecular movement," which (as long since shown by Mr. Robert Brown) is exhibited by almost any very finely-divided particles that are freely suspended in liquids.†

* See "Prin. of Gen. and Comp. Phys.," § 197.

† One of the most convenient methods of exhibiting this movement, is to rub-up a little Gamboge in water; for the resinous particles of this substance, being suspended by the gummy, will continue in motion for any length of time, even when completely secluded from the air, so that evaporation of the liquid can have nothing to do with it.

102. The *nuclei* of cells present numerous varieties of structure and aspect. In their simplest condition, they seem to be nothing else than assemblages of minute particles, sometimes of molecular minuteness, in other instances large well-defined granules; and among these may usually be distinguished some that are of an oleaginous character. In other cases, again, these assemblages of granules appear to have a distinct investment of their own, which separates them from the general cavity of the cell; this is most distinctly seen in pigment-cells and epidermic cells. At or near the centre of the nucleus, one or more corpuscles are frequently seen, very distinct from its general mass, which are termed *nucleoli* (Fig. 19, *c*); and these appear in many instances to have the character of minute vesicles. It is probable, however, that the term 'nucleolus' has been attached to bodies which are really very different from each other, both structurally and functionally; and there is yet much to be learned on the subject. The nucleus, as already stated, is usually found attached to the inner wall of the cell, and sometimes even appears to be imbedded in its substance; but it is occasionally observed to lie freely in the cavity. The *form* of the nucleus is for the most part nearly circular, and it may be usually observed to continue so, even when the form of the cell has undergone its most remarkable alterations, *e. g.* becoming fusiform or stellate;* but a very peculiar exception is presented by the nuclei of the "smooth" muscular-fibre-cells, which are staff-shaped (Fig. 79, *c*); this character serving to distinguish these cells from others which closely resemble them in form, but which do not possess their peculiar vital endowments. The *size* of the nuclei is more constant than that of the cells in which they are found; their usual diameter being from 1-4000th to 1-6000th of an inch. Hence the proportion of the cell which the nucleus occupies is extremely variable; for the whole cell-cavity is sometimes nearly filled by it, especially in young cells, so that it is difficult to make out the presence of a distinct cell-wall, unless by adding water or acetic acid which raises up the latter; whilst in other instances, especially when the cell is fully formed, the nucleus is comparatively small, being only from one-fourth to one-tenth of the diameter of the cell. The former condition is well seen in the chyle- and lymph-corpuscles; the latter in the pavement epithelium-cells (Fig. 19). That the *composition* of the nucleus is in some respects different from that of the cell-wall, is shown by the fact that the contact of acetic acid neither dissolves it nor renders it transparent, but on the contrary brings it into greater distinctness (partly by rendering the cell-wall transparent); it is not yet known, however, what is the precise nature of its component substance. It seems to be the general fact, that every Animal cell possesses a nucleus at some period or other of its life; and this nucleus seems to be usually persistent (as it is capable of being brought into view by reagents, when it is not otherwise apparent,) so long as the cell itself is undergoing developmental changes. But in the state of complete development, the nucleus sometimes disappears; thus it is normally absent in the red corpuscles of the blood of Mammals, and not unfrequently in fat-cells; and it is frequently seen to present a shrunken and

* A stellate nucleus is normally found in the cartilage-corpuscles of Cephalopoda, and abnormally in some cartilaginous tumours in Man. See Mr. Paget's 'Lectures on Tumours,' "Medical Gazette," Aug. 8, 1851.

wasted appearance in the cells of tissues which are undergoing degeneration. It will be presently shown, that there is strong reason to regard the nucleus as the chief agent in the vital operations of the cell; seeing that it can exercise its functions even without the development of a cell-wall to enclose the substances which it draws around it, and on which it exercises its peculiar powers (§ 117). Where two or more nuclei are seen in a single cell (Fig. 7), they may be regarded as originating in the subdivision of the primordial single nucleus, and as indicating the approaching subdivision of the cell itself, or the formation of a young cell within it.

103. The history of the Animal cell, in its simplest form, is precisely that of a Vegetable cell of the lowest kind. Every cell lives *for* itself, and *by* itself, like each of the solitary cells of the humblest Protophytes; and if the necessary conditions be furnished (these being essentially a due supply of nutriment, and a proper temperature), it may continue to live and to grow, and may go through all the phases of its development, quite independently of the organism of which it originally formed part. Of this we have numerous examples in the artificial implantation of parts of one body upon or within another; the graft uniting itself with its new stock, and continuing to grow after its own fashion at the expense of the nourishment thence derived. But a still more remarkable example is normally and constantly presented by the spermatic cells of certain animals, such as the Decapod Crustacea * and certain Nematoid Entozoa;† which are cast forth from the organs of the male in which they were generated, and are transferred into the body of the female, when as yet they are in a comparatively early stage of their own development; the spermatozoa being not yet formed within them, but being produced during the subsequent life of the cells, which apparently goes on as favourably within the generative passages of the female, as it would have done within the organs in which the spermatic cells were at first formed, the requisite conditions being duly supplied.‡ All the component cells of any one organism may be considered as the descendants of the primordial cell in which it originated; but the methods of their production are by no means the same in every instance, an end essentially the same being brought about by means which appear (at least) to be very different. The various modes of cell-development may however be reduced to two principal forms;—that, namely, in which the new cells arise *from* or *within* pre-existing cells, being produced by the subdivision either of the cells themselves, or of their nuclei, which is termed *endogenous* development; —and that in which they originate in germs developed *de novo* in the midst of an organizable 'blastema,' which has been prepared by a previous exercise of vital force, and which still requires the continued operation of that force *ab extra* for its due organization (§ 29). Each of these modes of *cytogenesis*, or cell-development, will now be separately considered.

104. The multiplication of cells by *duplicative subdivision*, which is the most common form of cytogenesis in the Vegetable kingdom, and which is particularly well seen in the simplest Cellular Plants (Fig. 5), is observed

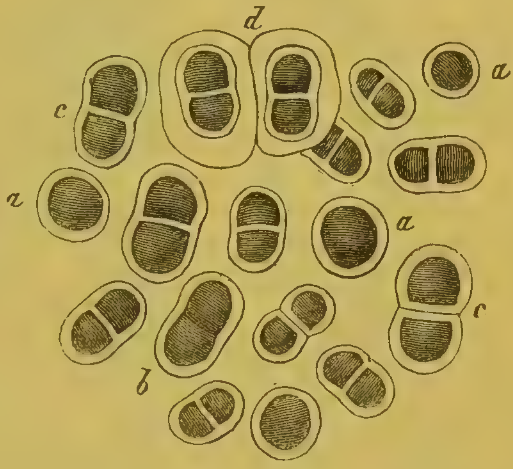
* Mr. H. D. S. Goodsir, in "Anatomical and Pathological Observations," p. 39.

† Dr. Nelson, "Proceedings of the Royal Society," June 19, 1851.

‡ For an application of this curious fact to the possible explanation of certain cases of *protracted gestation* in the Human subject, see CHAP. XIX.

to take place also within the Animal body, after a manner essentially the same, in most cases in which new parts are being developed in continuity with the old. The most characteristic example of it is seen in the early Embryo; which, at first consisting of but a single cell, has its number of cells augmented by such duplication, to 2, 4, 8, 16, 32, 64, &c. The same process may also be watched through the whole of life in Cartilage; and it is one of the means by which the Red Corpuscles of the blood are multiplied in an early stage of their development (§ 154). The commencement of this process in the Vegetable cell is indicated by its elongation, and by a slight hour-glass constriction (Fig. 5, *b*), which seems due to the tendency of the contents of the cell to separate into two halves; and between these a division is subsequently formed (*c*, *d*,) by the gradual infolding of the 'primordial utricle,' or inner cell-wall, which is the true representative of the wall of the Animal cell.* Where a distinct nucleus exists, however,—as is the case in most Animal cells—the process of subdivision seems frequently to commence in it; for before any distinct inflection of the cell-wall can be perceived, the nucleus may be seen to elongate, and to show a tendency to subdivision into two equal parts. Each of these, when completely separated, draws round it a portion of the contents of the cell; so that the cell-wall, which at first exhibits merely a sort of hour-glass contraction, is at last inflected so far as to constitute a complete partition between the two halves of the original cell; and these henceforth become two independent cells, which may go through the same process in their turn (Fig. 6, A—D). The repetition of this operation may take place either in the same or in the contrary direction, so as to produce four cells, either linearly arranged (E, F, G), or clustered together (H); and this duplication may go on upon the same plan, until a large mass has been produced by the subdivision of a single original cell. In ordinary Cartilage,† it is most common to see the cells forming clusters (Fig. 41); but in Cartilage which is being prepared for

FIG. 5.



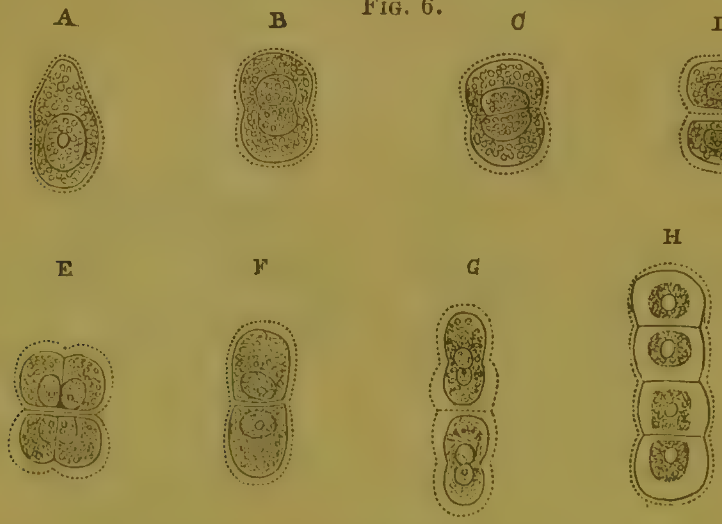

*Hæmatococcus binalis*, in various stages of development; *a*, *a*, simple rounded cells; *b*, elongated cell, the endochrome preparing to divide; *c*, *c*, cells in which the division has taken place; *d*, large parent cell, in which the process has been repeated a second time, so as to form a cluster of four secondary cells, such as is often seen in Cartilage.

* See "Prin. of Phys., Gen. and Comp.," pp. 91, 92.

† It is thought by Dr. Leidy, who has carefully studied this process in Cartilage (see his valuable paper 'On the Intimate Structure and History of Articular Cartilages,' in the "Amer. Journ. of Med. Sci.," April, 1849), that the direction of the subdivision is determined by that in which there is least resistance to the extension of the group of cells; but such can scarcely be the case in regard to the embryonic mass, the cells of which, if this were the sole determining influence, would continue to multiply on a uniform plan; instead of which, as soon as they have arrived at a certain degree of minuteness of subdivision, a diversity of arrangement begins to show itself in the component parts of what was previously a homogeneous assemblage.

ossification, we see long lines of cells, which have been obviously produced by the first of these methods of multiplication (Figs. 49, 50).

FIG. 6.




Multiplication of Cartilage-cells by duplication :—A, original cell; B, the same beginning to divide; C, the same showing complete division of the nucleus; D, the same with the halves of the nucleus separated, and the cavity of the cell subdivided; E, continuation of the same process, with cleavage in *contrary* direction, to form a cluster of four cells; F, G, H, production of a longitudinal series of cells, by continuation of cleavage in the *same* direction.

105. Not unfrequently, however, the multiplication of cells takes place, not so much by the subdivision of the pre-existing cell, as by the development of new cells in its interior; these appear to take their origin in the nucleus, which subdivides into two or more portions, each of them drawing a portion of the contents of the parent-cell towards itself, and becoming converted into a cell by the development of a cell-wall around this; and they gradually increase in dimensions, until they come to occupy the entire cavity of the parent-cell, and may so distend its wall, by their further enlargement, that it can no longer be distinguished. Of this method of cell-formation, also, we have examples in cartilage, especially in its early stage of development, when its growth is rapid (Fig. 7); but we there seldom see more than three or four cells thus generated within a parent-cell at any one time. It is in structures of more rapid growth, such as granulations,* and especially in cells of a cancerous or malignant

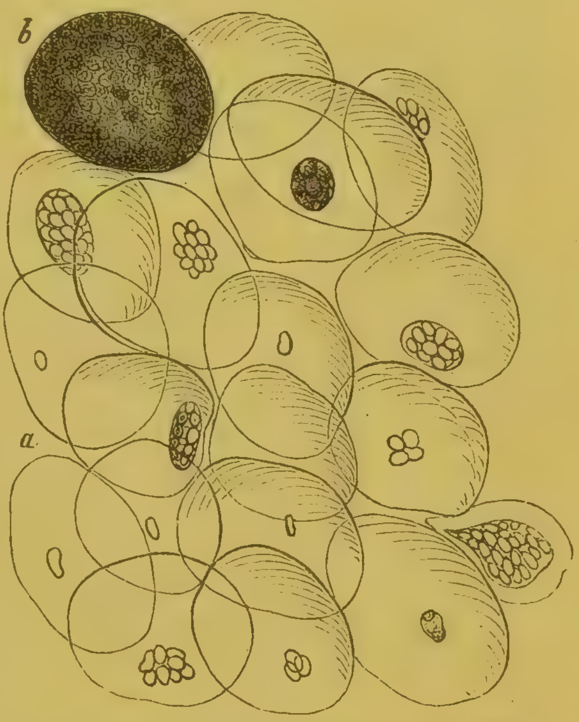
FIG. 7.

Section of branchial Cartilage of Tadpole of *Rana paradoxa*:—*a*, *b*, *c*, intercellular substance, with which the walls of the parent-cells are incorporated; *d*, single nucleus: *e*, nucleus dividing into two; *d'*, *e'*, two nuclei in one cell, formed by division of single nucleus; *f*, secondary cell, forming around nucleus *g*; *h*, two nuclei within single secondary cell; *i*, three secondary cells, within one primary cell.

* It is stated by Mr. Paget ('Lectures on the Processes of Repair and Reproduction after Injuries,' in the "Medical Gazette," 1849) that in granulations there are often to be found large compound cells of oval form, and as much as 1-250th of an inch in diameter, containing

character, whose speedy development and no less speedy degeneration are among their most distinguishing features, that we most frequently witness the subdivision of the nucleus into a considerable number of parts, and the development of numerous cells at one time within the cavity of each parent-cell (Fig. 8). The same method may often be recognized, however, in the development of cells within Glandular follicles; for where each follicle is a single parent-cell, and its nucleus remains persistent as a 'germinal centre' subsequently to its becoming a follicle by the rupture or thinning-away of a part of its cell-wall, it appears to be by the continual sprouting of new cells from this nucleus, that the materials of the secretion are eliminated from the blood (Fig. 25).—As a general rule, however, it may be remarked, that the production of a large number of cells within a single parent-cell only takes place when this new brood is *not* to form a permanent part of the organism, or to be itself the originator of a subsequent growth. It would seem, indeed, as if this rapid method of multiplication occasioned an exhaustion of vital force; so that the cells thus generated are incapacitated for any other purpose; whilst the comparatively slow method of duplicative subdivision may be repeated time after time, to an extent to which it is impossible to assign a limit, each pair of cells thus produced having an equal capacity with its progenitors for going through that process.

Fig. 8.




Endogenous cell-growth in cells of a Meliceritous Tumour:—*a*, cells presenting nuclei in various stages of development into a new brood; *b*, parent-cell, completely filled with a new brood of young cells, which have originated from the granules of the nucleus.

106. There are cases, however, in which cells are developed, without any direct connection with pre-existing cells, in the midst of a *blastema* or formative fluid poured out from the blood. Still it is uncertain to what extent this is to be considered as one of the ordinary modes in which the elements of the tissues are produced and increased; for it has been hitherto chiefly observed in cases in which a plastic exudation has been poured out for reparative purposes, or in which a structure of an abnormal character is being generated. The first step in the process usually appears to be the aggregation of some of the minute molecules which the fluid or semi-solid blastema contains, so that they form little rounded masses, or nuclei, from which the new cells originate. The mode in which the cell-wall is formed does not appear to be by any means constant. Sometimes it seems to rise and separate itself from the nucleus itself, as if it were formed by the melting-together of molecules

eight, ten, or more nuclei, which have been derived by subdivision from the nucleus of the simple cell, and which are probably destined to be the nuclei of as many separate cells.

precipitated upon or attracted to the nucleus; but more frequently it appears to be generated by the expansion of the wall of the nucleus itself; in either case, however, commencing to enlarge and separate itself from the nucleus by the endosmosis or assimilation of fluid from the surrounding blastema.* But there are other cases in which the nuclear particles appear to draw around them certain components of the substance in which they lie, before any cell-wall can be discerned, this being subsequently generated around this collection, which then constitutes the contents of the newly-formed cell. This first-formed nucleus may be persistent, and may take a part in the subsequent vital actions of the cell, of whatever kind these may be; or it may be superseded by a second nucleus, which subsequently makes its appearance in some other part of the cell-wall.—It seems probable that the first formation of the chyle- and lymph-corpuscles, which subsequently develope themselves into blood-corpuscles, takes place from free nuclei; and it has been maintained by some that the epidermis and epithelium are likewise formed in the same manner;—both these views, however, require confirmation.

107. Another mode of Cytogenesis must be mentioned as of occasional occurrence; namely, the expansion of a single apparently-homogeneous granule into a cell, without the previous formation of any perceptible nucleus; a distinction first showing itself between the exterior portion of the granule, which becomes the cell-wall, and the interior, which seems to melt-down to form the first cell-contents; and the former extending itself, as the latter augment by imbibition from the surrounding fluid. It is on this plan that the development of the 'zoospores' of many of the Algæ seems frequently to take place;† for these, at the time of their emission, can frequently not be considered as anything else than 'granules.' And the first development of blood-corpuscles in the Chick, as seen in blood drawn from the heart on the third day, is affirmed by Mr. Macleod‡ to present a similar series of phenomena. Indeed it may be surmised that when a large number of young cells are simultaneously or successively evolved from the nucleus of a parent-cell (§ 105), it is by some such mode of development from the individual particles composing the nucleus; for the appearance which is presented when this process is being carried on, is very much that of the sprouting of its marginal granules into young cells (Fig. 8). And it seems probable, that wherever a single granule is thus evolved into a cell, it has been discharged as a reproductive particle from a pre-existing cell; its conditions of development being in this respect different from those of the granules which form nuclei by their aggregation in the midst of a plastic exudation, and which, not having undergone the same preparation, are not endued with vital properties of as high a character.—On the whole of this subject, however, considerable obscurity still rests; and while it is next to certain that cells may be generated within the Human body in each of the modes now described, there is still very much to be learned respecting the conditions under which every form of the process respectively occurs.

108. We have now to inquire into the nature of those peculiar phenomena, of which Cells are the instruments, and to which the designation of

* See Prof. Bennett's Treatise "On Cancerous and Cancroid Growths," p. 146.
† See "Prin. of Phys., Gen. and Comp.," §§ 142, 267*a*.
‡ "Lond. and Edinb. Monthly Journ." Sept. 1842.

*Vital* is given, on account of their restriction to the living organism, and their distinctness from those of a physical or chemical nature. The series of actions constituting *Cell-Development*, under whichever of the foregoing modes it may take place, is, of all these phenomena, that which stands in most complete opposition to anything displayed by the Inorganic world; and we see in it the type of the development of the entire fabric, which essentially consists in the continual multiplication of its component cells by one or other of the processes just described, and in the subsequent changes which they undergo. Thus we observe the appropriation of certain nutrient materials, derived from external sources, in the first extension of the cell-wall, the enlargement of the nucleus, and the collection and increase of the cell-contents; and upon these materials a certain degree of transformation is commonly exerted. As already pointed out (§ 17), there is but little if any chemical change needed for the incorporation of the nutrient materials with which the Animal cell is supplied, into its own substance; the cell-walls and nuclei being apparently of the same chemical nature with the constituents of the blood, at the expense of which they are developed: but we must here recognize a *vital change*, in virtue of which they are rendered henceforth capable of exhibiting actions, which, so long as they remain mere chemical compounds, they are utterly unable to perform. The cell-contents, on the other hand, for the most part remain as mere chemical compounds; and though they are in many instances directly furnished by the nutrient fluid, there are other cases in which their composition is so different from that of anything it can be shown to include, that we must reckon, as one manifestation of the peculiar attributes of the cell, the power of *Chemical Transformation.* But its power may be also exerted in vitalizing its contents or a certain portion of them; this power of *Vital Transformation* being probably possessed in a low degree by many cells which prepare the nutrient material for its appropriation by the living tissues, but being pre-eminently the endowment of those which are concerned in the generative operations.— Thus, then, in the simple act of Cytogenesis, we recognize a force in operation, which converts certain chemical compounds into a living organized structure, not only moulding them into a peculiar and characteristic form, but endowing them with new attributes. And not the least remarkable of these attributes is that power of *increase* and *multiplication*, whereby the same alterations may be effected in an almost unlimited amount of raw material; so that an aggregation of organized tissue, sufficient to produce a fabric of considerable dimensions, may be thereby generated from a single primordial cell.

109. The history of the life of a Cell is by no means completed, however, by the fullest enumeration of the successional phenomena exhibited in its development and multiplication; for after it has attained its full growth, it may itself undergo alterations of various kinds, or may become the instrument of effecting changes in others, such as can scarcely be regarded in any other light, than as manifestations of a force identical with that which was operative in its original production.—Among the changes occurring in the cell itself, that which may be first noticed is the permanent alteration in *form* which certain cells undergo, not from forces external to them, but from agencies at work in their interior. Thus, although spheroidal cells may be converted into polygonal by mutual

pressure on all sides, or may be lengthened towards the fusiform shape when that pressure is less in one direction than in another, or may be flattened-down into a scale by the loss of its fluid, yet it is impossible to account in any such mode for the extraordinary elongation of certain cells, or for the flattening of others, when no pressure is being exerted upon them; or for the extension of offsets from others into caudate or stellate prolongations (§ 146). Some of these cases are not improbably to be accounted-for by the extension of the cell, whilst still increasing in size, in the direction of least resistance; in the same manner as the roots of plants send forth their prolongations, sometimes of extraordinary length, through the soil which they can most readily traverse. But there is reason to believe that such alterations of form may also be effected, even after the cells have attained their full dimensions, by the agency of currents within the cell, whose maintenance is intimately connected with its nutrient operations, and whose 'set' in particular directions determines the protrusion of the cell-wall at the points towards which they tend. It is well known that such currents are frequently to be observed in the cells of Plants; indeed it seems probable that they take place in every vegetable cell at a certain stage of its development.* Regular currents, apparently of a similar nature, and quite distinct from the 'molecular movements' which cannot be justly attributed to any other than physical causes (§ 101), have also been witnessed within many Animal cells: thus Prof. Sharpey has seen a clump of dark granular matter in regular revolution, and numerous separated granules coursing round and round, within the spheroidal pigment-cells of the tail of a Tadpole.† Prof. Czermak has described peculiar rotatory movements in certain vesicles attached to the fine extremities of the seminal tubes in the Salamander.‡ Prof. Kölliker has observed analogous movements in the cells of the seminal filaments of a Polyclinum, and in large cells in the sprouting arms of a Medusoid animal; § and a still more remarkable case, in which the currents within the cell distinctly determined the protrusion of the cell-wall in one direction or another, has been witnessed by the Author in one of the lowest forms of animal life, and has been elsewhere described by him in detail.||—On the whole, then, we seem entitled to affirm, that such permanent alterations in the forms of cells, as cannot be explained by external pressure, are dependent upon an agency of the same kind with that which is concerned in the ordinary operations of development; and must thus be regarded as a continued manifestation of what may be conveniently designated by the term *Cell-force.*¶

* See "Prin. of Phys. Gen. and Comp.," § 137.

† Introduction to Dr. Quain's "Elements of Anatomy," 5th edit., p. lvi. *note.*

‡ "Oester. Medic. Jahrbucher," Jan. 1845; and "Brit. and For. Med. Rev.," vol. xxii. p. 264.

§ "Entwick. der Cephalopoden," p. 156. || "Prin. of Phys. Gen. and Comp.", p. 244.

¶ The Author is particularly desirous that he should be understood as implying by this term, *not* that the force is produced or generated *by* the cell, but merely that the growth of the cell is the most general manifestation of that force, to which it is convenient to refer as a standard of comparison; and also that the cell affords the ordinary instrumental condition for the exercise of the force in question, although it can doubtless be exerted in many cases in which cell-development does not take place. The use which he would make of the term is just that which is commonly made of the term 'engine-power' in mechanics; for the steam-engine possesses no power in itself, but is simply the instrument most commonly employed, because the most convenient and advantageous yet devised, for the application of the expan-

110. Certain kinds of cells, however, exhibit more rapid changes of form, such as cannot be so directly attributed to their nutritive operations; and these may take place in such a manner, as to communicate *motion* to objects external to them. Moreover, these changes may take place altogether spontaneously (*i. e.*, independently of any external stimulation), or they may only occur when some exciting influence is communicated to the cell. Of both forms of movement, we have numerous illustrations in the Vegetable kingdom; the rhythmical undulations of the elongated cell-filaments of the Oscillatoriæ, or the alternating flexures of the stalks of the lateral leaflets of the Hedysarum gyrans, being examples of the former; whilst the closure of the fly-trap of the Dionæa, the folding of the leaves of the Mimosa, and the flexure of the stamen of the Berberry, upon mechanical or chemical stimulation, are specimens of the latter. In all these cases, the aptitude for the movement, whether 'spontaneous' or 'excited,' is so clearly dependent upon the general vital activity of the cells which perform it, that we can scarcely regard it in any other light than as an expression or manifestation of their peculiar force. And this view derives confirmation from all that we know of the conditions under which movement is originated in Animals. For here, too, may it be said that all motion is dependent upon the change of form of cells; and that this change may be either 'spontaneous' or 'excited,' but in both cases must be regarded as a manifestation of vital force. Of the spontaneous movement, we have the most remarkable example in the incessant rhythmical action of the *cilia* (Fig. 21) which line many of the tubes and cavities of the body; these cilia being, it would appear, nothing else than prolongations of the cell itself, though of extreme tenuity. Their movement is obviously dependent upon the life of the cell from which they are put forth, and is retarded or brought to a stand by agencies which tend to depress its vital power. But these are not the only cases in which cells appear to undergo rhythmical changes of form, as a part of their regular vital operations; for the alternating contractions and dilatations of the cavities of the heart appear due to an action of this kind in its *muscular* walls; and we may not improbably regard the contraction of the uterine structure, when it has reached a certain stage of its development, in the same light. In both these cases, it is true, it is to be observed that the structures in question are peculiarly amenable to the influence of stimuli; thus the rhythmical action of the heart may be re-excited, after it has been suspended, by a slight mechanical irritation, and its regular movements may be either accelerated or retarded by nervous influence; so, again, the parturient efforts of the uterus may be induced, when they would not otherwise take place, by mechanical or nervous stimulation, or, when they are already going on, they may be accelerated or retarded by the same agency. But still, when every source of excitement is excluded, we cannot but perceive that these actions take place with a *spontaneity* which can scarcely be accounted for in any other way, than by considering them as expressions of the vital activity of the component cells of these forms of muscular tissue, which manifests itself in this mode when the developmental life of the cell has attained its

sive force of steam, generated by the application of Heat, to the production of mechanical motion; this Heat, which is the real motive power, being capable of manifesting itself in a great variety of other modes.

maturity. And this view is strikingly confirmed by what we know of the origin and termination of these movements. For the action of the heart commences, when as yet its contractile parietes consist but of an assemblage of ordinary-looking cells, no proper muscular tissue being evolved, and no nervous system being yet developed from which the stimulus to the movement can proceed; and it is impossible to assign any other cause for the movement under such circumstances, than the attributes inherent in the tissues which perform it. So, again, as will be shown hereafter (CHAP. XIX., SECT. 3), the parturient action of the uterus cannot be fairly attributed to any of the agencies which have been supposed to excite it; but must be looked upon as one of those phenomena, whose periodical recurrence is due to the regularity of the operations of growth, whereby the tissue attains its maturity in a certain limited time, and then discharges itself of its vital force in the shape of motor power; just as another cell will consume it in the development of a brood of young ones, or in the performance of chemical transformations, setting free the product, when completely formed, by its own rupture or deliquescence. And the subsequent result is just what on this view might be anticipated; for the vital power of the tissue being thus exhausted, it speedily undergoes degeneration and death; and thus it is that the reduction of the uterus to its normal size takes place so much more rapidly after parturition, than does the wasting of ordinary muscles by simple disuse. Hence we may look upon the development of the muscular substance of the uterus, which is going on during the whole period of gestation, as in reality consisting in the accumulation of a vast reservoir of cell-force, which is to be consumed in one powerful effort.—The contraction of the muscles ordinarily termed 'voluntary,' which also will be shown hereafter to be dependent upon changes of form taking place in the cells of their component fibrillæ, is not of the 'spontaneous,' but of the 'excited' kind; but here, too, we have evidence that the mechanical movement is to be regarded but as an expression of vital force, in the fact (now universally admitted by Physiologists) that every act of muscular exertion necessarily involves as its condition the disintegration of a certain amount of muscular tissue, whose components are then removed as effete by the excretory processes; so that we may look upon the death of such cells, whose term of life might otherwise have been considerably prolonged, as the result of the expenditure of their peculiar modification of force, under the guise of mechanical power.

111. What has been said of the cells which possess the attribute of *motility*, is also true of that still more remarkable order of cells, peculiar to the Animal kingdom, by whose agency *Nerve-force* is developed. The nature of this force, and its relations to Electricity and other physical agencies, will be discussed hereafter (CHAP. V. SECT. 7); but at present it will be sufficient to state, that there can be no reasonable doubt of the dependence of its production, in the *central* organs, upon the development of the peculiar cells which constitute their ganglionic or vesicular substance; and that the progress of physiological inquiry seems to justify the belief (long since entertained and expressed by the Author), that cells or cell-nuclei are usually the agents in the origination of nerve-force at the *peripheral* extremities of the nerve-fibres. This nerve-force may be regarded as the very highest manifestation of Vital Power, in virtue alike of its intimate relation with Mental agency, which it serves to excite, and by

which it is in turn excited (CHAP. XIV.), of its power of exciting or checking Muscular movements, and of the control it exerts over the Vital operations of cells in general, whether these take the form of multiplication or of chemico-vital transformation, or present themselves under any other aspect. For so obvious is the controlling and regulating action of the Nervous System, where (as in Man), it attains its highest development, over those acts of nutrition, secretion, &c., which essentially consist in the production and growth of cells, that many Physiologists have regarded these actions as necessarily *dependent* upon the exercise of nervous power. For this assumption, however, there is no evidence whatever; and it is strongly opposed by the fact, that these actions are performed under conditions essentially the same as they are in the Vegetable kingdom, in which nervous power has no existence. And all the phenomena which have been adduced in its support, are fully capable of being scientifically expressed by the view here advocated; for just as Electricity developed by chemical change may operate (by its correlation with chemical affinity) in producing other chemical changes elsewhere, so may Nerve-force, which has its origin in cell-formation, excite or modify the process of cell-formation in other parts, and thus influence all the vital manifestations of the several tissues, whatever may be their own individual characters.— Further, we have evidence in the phenomena of Nervous action (CHAP. V. SECT. 7), that the production of Nerve-force, like the development of Muscular power, involves the degeneration and death of a certain amount of the tissue which serves as its instrument; so that we are furnished by this fact with an additional reason for the belief, that nervous agency is to be regarded as but a peculiar *modus operandi* of the same force as that which is elsewhere operative in cell-development.

112. Thus, then, we have distinguished the following as the principal manifestations of Cell-Life:—

- *a. Growth* of the original cell, from its germ to its maturity; involving the *selection* and *appropriation* of its materials.
- *b. Multiplication*, by the subdivision either of the original cell or of its nucleus.
- *c. Chemical Transformation*, exerted upon the *pabulum* of the cell, whereby new products may be generated in its interior.
- *d. Vitalization* of a portion of the pabulum, whereby it becomes endowed with vital properties of its own, so as even to originate cells *de novo*.
- *e. Permanent Changes of Form*, taking place in connection with acts of growth, and giving a peculiar character to the tissue.
- *f. Temporary Changes of Form*, applied to the generation of mechanical force, and to the production of sensible motions.
- *g. Production of Nerve-Force*, which may affect all the preceding operations, and which is intimately related to Mental agency.

The first five of these are manifested in those *constructive* operations, which are common alike to the Plant and to the Animal, and which consist in the building-up of the organized fabric. Of this organized fabric, on the other hand, the exercise of the last two may be regarded as essentially *destructive;* since they involve an expenditure of that force which previously held together the components of the tissues, whereby these com-

ponents are given up to the disintegrating agency of the Chemical and Physical forces. But it is in the exercise of Nervo-Muscular power that the Life of the Animal essentially consists; and the constructive operations which take place in its fabric (as will be more fully shown hereafter, CHAP. VI.), may be regarded as essentially destined to provide its material and dynamical conditions.

113. That these various phenomena are to be regarded as manifestations of one and the same Vital Force, of which the several modifications of Organic Structure that exhibit them are the respective instruments, may be argued, not merely from the facts already urged, but also from the community of origin of all the tissues and organs of each individual, in a single primordial cell. For, like the humblest forms of Vegetable and Animal life which permanently consist of separate and independent cells, the embryo of even the highest types of each kingdom, in the earliest phase of its development, is but a single cell; and during the earlier period of its increase, we observe that it displays only that *most general* manifestation of cell-force, which consists in growth and multiplication. The descendants of this parent-cell, however, soon begin to undergo a variety of transformations, and to assume a diversity of characters; and we observe, in fact, that a sort of 'division of labour' takes place among them, each group of cells being appropriated to some particular office, and discharging it alone to the exclusion of the rest; as if, by this special direction of the vital force, the cell which is its instrument is unfitted for any other kind of vital agency. Of this *relation of reciprocity* between the several manifestations of vital power, the following examples, among many others, may be cited.—Where the whole energy of the cell is directed to *multiplication*, we do not observe either chemical transformation, or change of form, or development into any other tissue; nor do we find that either motor power or nerve-force is generated. Of this we have already had an example in that early phase of embryonic life, in which cell-multiplication takes place with extraordinary rapidity. In the formation of new parts which make their appearance at a subsequent time, we find that their foundation is laid in a mass of cells which rapidly multiply, up to a certain point (like those of the embryonic mass), without any change of form or character; and that, when they have once begun to undergo development into other kinds of tissue, they multiply no longer. So, again, in those cancerous growths, whose rapid increase is one of their most important distinctive features, we usually observe that the whole texture retains its primitive cellular character; and that the development of higher forms of tissue only occurs in those whose growth is slower, their cells having ceased to multiply themselves thus rapidly, when they underwent histological change. But perhaps one of the most striking examples of this principle is presented by those glandular follicles which act as parent-cells, developing in their interior a successional progeny, which are the true *secreting* cells: for the former possess no secreting power, their vital force being expended in the production of the latter; whilst, on the other hand, the latter possess no reproductive power, but die and are cast off when they have reached their maturity, even their own cell-walls being usually very imperfectly developed (§ 117), as if their whole vital force had been expended in the secreting process.—So, again, the cells whose vital force is exerted in *mechanical movement*, seem

exclusively adapted for this purpose, apparently performing no other vital changes than those involved in their own development. Thus, the ciliated epithelium-cells which line the respiratory passages and the ducts of many glands, appear never to perform that secretory function which is discharged by other non-ciliated cells of the same stratum; so that, their mode of production and the general conditions of their development being essentially the same, we can scarcely fail to regard the ciliary movement and the secreting action, as, however dissimilar in themselves, two modes of operation of one and the same 'cell-force.' Again, the elongated cells which constitute the non-striated muscular fibre, and the minute cellules of which the fibrillæ of the striated muscular fibre are made up, seem to exercise no chemical change, to undergo no further development, and to undergo disintegration without having previously multiplied themselves; so that all increase and regeneration of muscular tissue appear to take place, either by production *de novo*, or possibly (in the case of the striated fibre) by the continued development of new cells from the nucleus of the parent-cell, which, like that of the glandular follicle, performs no other function than that of multiplication. —The cells composing the nervous tissue, again, do not show any indication of reproductive power, and seem to undergo disintegration as the direct consequence of their production of nerve-force; so that they, too, appear to expend their whole vital energy in one particular mode of action, and to have no power to spare for any other.

114. We have hitherto spoken only of that part of the Life of the Cell, which intervenes between its origin and its epoch of maturity; we have now to advert to its decline and death; and these are to be regarded, no less than the preceding, as part of that regular series of changes by which it is distinguished as an organized structure. For it may be stated as a general rule, that the *amount of vital action* which can be performed by each living cell has a definite limit; and that when a certain point has been once reached, a diminution in the vital activity of the cell must ensue, and it must become more and more subject to those influences which are constantly tending to degrade it to the condition of inorganic matter. Hence there is for the most part a limit to the *duration* of each component cell of the organism, which is quite irrespective of that of the organism at large; the life of the latter being maintained by the continual development of new tissues, in the place of those which are degenerating and decaying. But this limit is by no means constant; since a cell may live faster or slower, that is, it may put forth a greater or less degree of vital energy in a given time, in accordance with the conditions under which it is placed; and the more rapid the rate of life, the more brief, *cæteris paribus*, is its duration. Of this general principle, abundant examples are afforded to us in the Vegetable kingdom, in which we can readily trace the operation of varying degrees of light and heat; but it is not difficult to trace them out also in cold-blooded animals; and the only reason for the greater constancy in the rate of decay and renovation of the tissues in warm-blooded animals, seems to lie in the uniformity of the temperature at which they are kept, which uniformity tends to produce a determinate regularity in the rate of their vital activity (§ 127). As already remarked, the very influences which call into action the vital properties of a living tissue, tend to produce its decay, when it no longer possesses

the faculty of turning them (so to speak) to this account; and thus it is that, in warm-blooded animals, the cessation of those changes in which life consists, immediately leaves the way clear for that disintegration which is effected by Chemical forces, and this the more actively as the temperature is higher. The only tissues, indeed, that can resist the operation of these forces, are such as, in virtue of their peculiar composition, are not readily affected by them. Thus we find that bones, teeth, hairs, &c., may have their existence almost indefinitely prolonged, without any sensible degeneration, after the complete cessation of all vital changes in their substance; since that very consolidation of these tissues, which put them out of the pale of active life, at the same time rendered them less subject than before to the degrading influence of Chemical agencies. Even the softest and most decomposable of the tissues may be preserved from decay, provided that they are either kept at a sufficiently low temperature, or are entirely secluded from oxygen, or are completely deprived of their moisture; either of which conditions is incompatible with the persistence of vital activity. And thus it happens that not only the seeds of Plants, but many Animal organisms of a high degree of development, may be kept in a dormant condition for an unlimited period, by the reduction of their temperature or the withdrawal of the liquid components of their structure; ready for a renewal of their vital activity, whenever the deficient conditions may be supplied.*

115. The different behaviour (to use a term now naturalized in Chemical Science) of the *living* and of the *dead* organism under the same conditions, is commonly accounted for by the supposition, that the Vital force, so long as it endures, antagonizes the operation of the Physical and Chemical agencies, which are constantly tending to the disintegration of the living structure; and that, so soon as the former is extinct, the latter can exert their influence without restraint or opposition. But against this doctrine, several cogent objections may be adduced. For in the first place, the conditions most favourable to the decay of the organism after its death, are those which are not only most favourable, but are absolutely essential, to its life, whilst it retains its vital properties; the presence of *Water* being requisite for all the transformations which the nutrient materials undergo, as well as for the very construction of a cell; the presence of *Oxygen* being necessary for the greater number, if not for the whole, of the chemical actions which the life of the cell involves; and the dynamical agency of *Heat* being so completely indispensable, that the amount of Vital Action put forth may be almost considered as the definite equivalent of the amount of this power that is in operation.† But if more than *a certain measure* of these powers should be exerted, the effect is not beneficial, but injurious, to the living organism, which is then acted-on as if it were composed of dead matter. Thus we see that whilst to every living being there is a certain range of temperature, more or less limited, within which its vital activity is normally exercised, any considerable elevation above that standard occasions a perversion of that activity, which tends to its destruction; and a heat sufficient for the decomposition of its organic constituents is not less effectual in producing

* See "Prin. of Phys., Gen. and Comp.," CHAP. III., SECT. 4.
† Op. cit., CHAP. III., SECT. 3.

this change on the living body, than it is on the dead. So, whilst the respiration of atmospheric air is necessary for almost every manifestation of life, the introduction of undiluted oxygen into the system is speedily fatal, apparently through the violence of the actions which it excites.—So again, if we observe the operation of other agencies than those to which reference has hitherto been principally made, we notice that they either modify its vital action, or entirely destroy its vital activity. Thus, a moderate current of Electricity appears to promote or retard the nutritive or other operations, according as it favours or antagonizes the chemico-vital changes which they involve;* whilst a violent shock is at once destructive of life, a more powerful discharge being required as the bulk of the animal is greater. So, again, we find that various Chemical agents exert a very definite influence on the living body; their forces not being kept at bay by its Vital powers, but manifesting themselves either in the modification of its vital operations, or in the destruction of its living tissue. Of the former class of effects, we have a good illustration in the action of what are termed the *irritant* poisons; these, for the most part, being substances which are known to have a definite chemical relation to the components of the living tissues, and which tend, by entering into new combinations with them, to interfere with those changes in which vital activity essentially consists. Thus Arsenic and Corrosive Sublimate form combinations with Albumen, of such stability that they are among the most perfect preservatives of dead tissues which we possess; and hence, even if they do not absolutely withdraw the Albuminous constituents of the living tissues from their normal combinations, they *tend* to do so, and by thus interfering with the action of the vital forces, occasion that perversion of the nutrient operations which manifests itself as Inflammation.† A more energetic Chemical action is exerted, however, by the *Corrosive* poisons, which operate upon the living tissues, not in modifying their vital activity, but (by completely changing the state of their organic constituents) in putting a complete and entire check to it; and there is no reason to regard the Chemical changes which they occasion in the living tissues, as in any degree different from those which they would effect on substances of the same composition not endowed with life. A still more remarkable influence is exerted by those 'ferments' or *Septic* poisons, which have a special power of exciting and promoting decomposition in the components of the tissues (§ 19); for of these, the introduction of an extremely minute quantity into the organism is sufficient to pervert or even to destroy its entire vital activity. Those of the less potent kind appear to act, not by at once checking the nutritive operations, but by lowering or degrading them; accelerating the stage of degeneration in the tissues which are already in a state of vital activity, and preventing the newly-originating tissues from attaining their normal perfection either of structure or of action, so that the degenerative stage in them also is more speedily induced. But there are some which appear to be capable of putting an almost immediate stop to all the vital operations of the system, in virtue of the changes of composition which they effect; and here too we observe, that the poisons which are

* "Prin. of Phys., Gen. and Comp.," §§ 107—112.

† This condition will be shown hereafter (CHAP. XI. SECT. 3) to involve a *lowering* of the vital powers of the solid tissues which it affects.

most powerfully destructive of life, are those which induce the most rapid degradation of the organic components of the tissues to the state of inorganic compounds, as is shown by the very speedy decay of the bodies of those who have died from the bites of serpents, malignant fevers, &c., a state of putrescence manifesting itself in many instances even before life is extinct.

116. Thus, then, we may state it as a general fact, that, so far from the Living Organism having the power of resisting the operation of Chemical and Physical Agencies, it is completely amenable to them: but that certain of them exert their influence upon it in a mode very different from that in which they act on dead matter, affording, in fact, the material and dynamical conditions requisite for the maintenance of its vital activity; whilst others modify and pervert that activity without destroying it, so as to give rise to morbid actions; the effects of others, again, being so completely antagonistic to all vital activity, that it is at once checked by them. And we shall hereafter see reason to believe, that just as the unorganized *pabulum* provided for the nutrition of the structure, is converted by the act of Organization into the living cell, so the Physical and Chemical forces whose influence promotes that organization, are really metamorphosed (so to speak) into Vital power by the instrumentality of the cell-germ, so that all the forms of 'cell-force' are thus immediately derived from them. It is, however, inherent in the very nature of the living organism, that this instrumentality should only persist for a limited time. The changes involved in the process of organization have the effect of rendering the organic structure less and less instrumental in determining this metamorphosis of force; and thus a time arrives, when the capacity of development is exhausted, and when the physical and chemical forces, no longer turned to the account of vital activity, begin to exert a disintegrating power. Hence in the Life of each cell, there is a period in which its peculiar attributes are undergoing augmentation, an epoch of perfection, a period of decline, and an epoch of entire cessation; and the latter is forthwith succeeded (save in the exceptional cases already referred to, § 114), by the decay of the structure. And in proportion to the degree of vital energy which the cell possesses (that is, to its power of turning Chemical and Physical agencies to its own account, instead of being itself perverted by them), will it be able to resist the operation of influences which tend to its disintegration. All this is true, as will be shown hereafter (SECT. 3), of the organism at large, as well as of the single cell; in fact, the entire organism, commencing in a single cell, and developed through the multiplication of cells, may be considered, even at its fullest development, as exhibiting, distributed (as it were) through its various component parts, all those attributes which have now been described as characteristic of cells in general; and the phenomena, not merely of normal life, but of disease, and of the influence of morbific and remedial agents, will be found to be so many illustrations of the doctrines now enunciated. It is indeed surprising, that with this mass of familiar facts continually presenting themselves to the observation of Physiologists, any such doctrine should have held its ground, as that the living organism withdraws its components from the domain of Physical and Chemical forces; and only restores them to the authority of these, when it has itself lost the supremacy of the "Vital Principle" or "Organic

Agent" which was supposed to hold possession of the living organized body.

117. Of *Free Nuclei and their Actions.*—Although the 'Cell' has been spoken of as the type of organic structure, and the 'Cell-force' as the most general form of vital agency, yet it must not be left out of view that there is strong evidence of the presence of similar attributes in bodies resembling cell-nuclei, which, although they may never go on to be developed into cells, appear to be the instruments of vital operations of a very determinate kind. This is especially the case, as first pointed out by Mr. Simon,* in the case of the so-called "Vascular Glands," whose elaborating influence is exercised upon materials which are withdrawn from the current of the circulation only to be restored to it again; there being here obviously not the same necessity for a limitary membrane, as where the material drawn by the nucleus of the secreting cell around itself, is destined to be completely separated and to be cast forth through another channel. There are various cases, however, even among the ordinary secreting structures, in which the cell-membrane seems to be wanting, free nuclei being found both in the organ and in the secreted fluid; this is especially the case, for example, in the gastric glands. And generally it may be remarked, as Mr. Simon has pointed out (*loc. cit.*), that the cell-wall of secreting cells is much less perfectly formed than that of the cells which are to remain as components of the solid tissues, and has a much greater tendency to deliquescence, whereby the contents of the cell are set free.—Again, the presence of nuclei appears to exert an influence, as will be presently shown, on the production of *fibres* in the midst of an organizable blastema; and there seems reason to think, also, that the yellow or elastic fibres are formed by the linear extension of the nuclei themselves (§ 224). Some forms of *basement-membrane*, too, seem to be composed of aggregations of nuclear particles, which not improbably serve as the instruments of promoting vital operations in organizable fluids in their proximity.—These facts concur with those already cited (§ 102), to support the view that the *nucleus* is that component of the Cell, through which its peculiar powers are chiefly exerted.

118. *Of Simple Fibres; their Formation and Properties.*—That *all* the Animal tissues have their origin in Cells, so that even the widest diversities of type are reducible to the same category, was the doctrine originally put forth by Schwann, who first attempted to generalize the phenomena (most of them discovered by his own observations) which are presented by their development. By subsequent research, however, it has been shown that this statement was too hasty; and that, although many of the tissues retain their primitive cellular type through life, and many more are evidently generated from cells which subsequently undergo metamorphosis, there are some in which scarcely any other cell-agency can be traced, than that concerned in the preparation of the plastic material. This would seem to be the case especially with those *Simple Fibrous Tissues*, hereafter to be described (CHAP. V., SECT. 1), which make up a very considerable proportion of the bulk of the body. For although it seems indubitable that they *may* be formed by the transformation of cells, and although they probably *are* thus generated in the first development of the

* "Physiological Essay on the Thymus Gland," p. 84.

organism, yet their subsequent production (especially in the reparation of injuries under favourable circumstances) seems to be effected by the fibrillation of an 'organizable blastema' (§§ 26–28). Even here the course and direction of the fibres seem often to be determined by the nuclear particles which the fibrillating substance includes; for in the reproduction of tendinous tissue, as observed by Mr. Paget,* the nuclei are formed and become elongated *before* any fibrillation is visible, and the fibrillation takes place in the direction in which they lie, so that each nucleus is imbedded in a fasciculus of fibres; and a similar relation has been pointed out by Mr. Addison,† who has remarked that the fibres which are formed during the coagulation of the Liquor Sanguinis or in other plastic exudations, often seem to radiate from the cells or nuclear corpuscles which these fluids may contain (Fig. 9). These facts give a sufficient explanation of the presence of nuclei in the midst of the simple fibrous tissues, which has been adduced in support of the doctrine of their origin in cells.—A very marked example of the production of fibres in the midst of an organizable substance, without any direct intervention of cells, is afforded by *Fibro-Cartilage;* the various forms of which present every gradation between the perfectly homogeneous intercellular substance of ordinary Cartilage (Fig. 41) and a distinct fibrous tissue (Fig. 42). Here, too, it is possible that, although the fibres do not themselves originate in the transformation of cells, the cells of the cartilage may exert such a determining agency in their production, as appears to proceed from the nuclei in the cases previously referred to.—Of all the varieties of Fibrous tissue thus generated, it may be stated that their function is simply mechanical; that consequently the performance of that function does not depend upon a continuance of vital activity; and that they do not seem to possess that power of *self-formation* which is characteristic of the cellular tissues, but for the most part depend, for their production, maintenance, and regeneration after injury, upon the formative power of the Blood (§ 224).

FIG. 9.

Cells with radiating Fibres, from the fluid of the vesicles of Herpes labialis.

119. *Of Simple Membrane; its Formation and Properties.*—In many parts of the Animal body, we meet with membranous expansions of extreme delicacy and transparency, in which no definite structure can be discovered; and these seem, like the simple fibres just described, to have been formed rather *directly* from the nutritive fluid, than indirectly by any process of transformation. The characters of this kind of membrane were first pointed out by Mr. Bowman,‡ and Prof. Goodsir,§ by the

* 'Lectures on the Processes of Repair and Reproduction after Injuries,' in "Medical Gazette," 1849, vol. xliii. p. 1071.

† "Second Series of Experimental Researches on the Process of Nutrition in the Living Structure," p. 5; and "Third Series," p. 7.

‡ See his Memoir 'On the Structure and Uses of the Malpighian Bodies of the Kidney' in the "Philos. Transact.," 1842; and the "Cyclopædia of Anatomy and Physiology," vol. iii., Art. 'Mucous Membrane.'

§ "Anatomical and Pathological Observations," p. 3.

former of whom it was named *basement*-membrane, as being the foundation or resting-place for the epithelial or epidermic cells which usually lie upon its free surface; whilst by the latter it was termed the *primary* or *germinal* membrane, as furnishing (in his opinion) the germs of those cells.—In its very simplest form, the basement-membrane is a pellicle of such extreme delicacy, that its thickness scarcely admits of being measured; it is to all appearance perfectly homogeneous, and presents not the slightest trace of structure under the highest powers of the microscope, appearing like a thin film of coagulated gelatine. Examples of this kind may easily be procured, by acting on the inner layer of any bivalve shell with dilute acid; this dissolves away the calcareous matter, and leaves the basement-membrane. In other cases, however, the membrane is not so homogeneous; a number of minute granules being scattered, with more or less of uniformity, through the transparent substance. And we not unfrequently find, in the place of these uniformly-distributed granules, a series of distinct spots, arranged at equal or variable distances, and lying in different directions; of this Prof. Goodsir has adduced a good example in the membrane of the intra-glandular lymphatics.* Moreover, the membrane thus constituted is disposed to break up into portions of equal size, each of which contains one of these spots; whilst in the more homogeneous forms previously described, no appearance of any definite arrangement is perceptible when they are torn. Hence it would seem as if the first and simplest form were produced by the simple consolidation of a thin layer of homogeneous fluid; the second by a layer of such fluid, including nuclear particles; and the third by the coalescence of flattened cells, whose further development has been checked, but whose nuclei may still continue to perform their characteristic functions.—It is probable that the primary membrane exists, under one or other of these forms, on *all* the free surfaces of the body; though it cannot be everywhere demonstrated. Thus it appears to constitute the outer layer of the true Skin, lying between its fibrous substance and the epidermis; it lines all the cavities formed by Mucous membranes, and is prolonged into all the ducts and ultimate follicles and tubuli of Glands which are connected with them, being, indeed, with the exception of the epithelial cells which cover its inner surface, the sole constituent of some of these; it forms the innermost layer, also, of the Serous and Synovial membranes, there, also, supporting the epithelium; and it lines the blood-vessels and lymphatics, forming the sole constituent of the walls of *their* minutest divisions. In all these cases, its function appears to be, in part at least, the limitation of the too free transudation of fluid; a sufficient amount being allowed to pass, however, for the wants of the tissues which it cuts off from direct relation with the blood. Thus, the epidermic and epithelial cells of the skin, mucous membranes, &c., draw their nourishment, through the basement-membrane on which they rest, from the vessels of the subjacent tissue; just as the tissues which are themselves permeated by capillary vessels, can only draw nutrient materials from the interior of the latter, through the membrane which constitutes their walls.—But it seems probable that this membrane usually performs a much more important office, than that of simply limiting the fluids, whilst allowing the requisite degree

* "Anatomical and Physiological Observations," pp. 46, 47.

of transudation; for there is strong reason to believe, that it has an important instrumentality in the production of the cells which are continually originating on its surface, either by itself furnishing their germs, or (in the case of the epidermis) by promoting the development of cells *de novo* in the organisable blastema which lies beneath its deepest layers. The mode in which these cells originate, however, will become the subject of discussion hereafter (CHAP. V., SECT. 2).

### 2. *Of Vital Force, and the Conditions of its Exercise.*

120. When we pass from the mere observation of the elementary phenomena of Life, described in the previous section, to the search for their causes, we find that, as in other cases, the conditions of all Vital changes are twofold, namely, *material* and *dynamical* (INTRODUCTION, p. 3);—the former consisting in the due supply of the appropriate pabulum for the development of organic structure; the latter, in the exercise of a force or power whereby this is organized and vitalized.—The Animal cell cannot, like that of the Plant, generate its pabulum for itself out of the inorganic elements around it; but is dependent upon that which has been prepared for it; and in Man, as in all the higher forms of Animal existence, this pabulum is furnished to each growing part by the circulating fluid, which has been prepared by previous operations. It is the essential character of this fluid, that it contains the materials ready to be appropriated by the walls and nuclei of cells, which are probably, as we have seen, of uniform composition; and the material of the simple fibres and membranes, also, is yielded by the essential components of the blood, in a state in which it seems readily to undergo the requisite transformation. The contents of the various groups of cells forming part of the organism, are, however, extremely varied; and no particular order of these can be generated, unless the nutritive fluid contain the materials for them, either ready formed, or in a state in which the cell itself can produce them by a process of chemical transformation. Thus, Adipose tissue cannot be formed, unless there be fatty matter in the blood; the Red Corpuscles cannot be produced without a supply of iron; the Secreting cells of the Kidney require for their development a supply of urinary matter;—and so on. But further, there is evidence that the presence of a particular substance in the nutrive fluid *determines* the development of the particular kind of cell of which it is the appropriate pabulum, provided that the other requisite conditions are supplied. Thus, an increase of Adipose tissue takes place, when the blood habitually contains an unusual amount of fat; an augmentation in the proportion of the Red Corpuscles of the blood may be distinctly observed (especially if they have been previously diminished unduly), when an additional supply of iron is afforded (§ 174); and when one of the kidneys has been removed, or is prevented by disease from performing its normal duty, the other, if it remain healthy, undergoes an extraordinary increase in size, so as to perform the duty of both organs, the augmented development of its secreting structure being here also fairly attributable to the accumulation of its appropriate materials in the blood. This principle is one most fertile in Pathological applications; for there can be little doubt that the development of many morbid growths is due, not so much to a perverted local action, as to the presence

of certain morbid matters in the blood, which determines the formation of tissues that use them as their appropriate pabulum. Such is pretty obviously the case with those disorders, which (like the Exanthemata) are universally admitted to be of 'constitutional' character, and which are distinctly traceable to a poison introduced through the blood, whose first influence is exerted in modifying the physical and vital properties of that fluid; and the evidence has been of late accumulating, that it is true also of the various forms of Cancer, the local development of an abnormal structure being in this case, also, nothing else than the manifestation of the existence of that peculiar matter in the blood, which is the appropriate nutriment of its component tissues, — or, as Mr. Simon appropriately designates it, "a new excretory organ, which tends essentially to acts of eliminative secretion, just as distinctly as the healthy liver or the healthy kidney."*

121. But however abundant may be the supply of the nutritive materials, and however complete may be their preparedness for organization, they can no more become organized into cells by their own powers, than a mass of iron could shape itself into a steam-engine or a spinning-jenny. They need to be acted-on by the appropriate *force;* and this we have seen to be, in the first place, the vital power of a pre-existing organism. For whether new cells are formed by the subdivision of previous cells, or sprout from the granules of their nuclei (either within the parent-cell, or after being set free from it), or originate in an organizable blastema, we trace that influence everywhere exerted. When the cell reaches a certain stage of its development, however, it becomes self-dependent; being capable of maintaining its own life, if the material conditions be supplied, without the assistance of vital force imparted to it from without; and in its turn, it comes to impart a similar power to the germs which it may itself prepare, or to the plastic fluid which it may assist in elaborating.

122. But the question next arises, what is the original source of that Organizing force, which the cell receives during the early stage of its development, and which it subsequently itself exerts upon the nutrient matter it appropriates? And to this question it seems now possible to give a more satisfactory answer, than that with which Physiologists were formerly obliged to satisfy themselves. For it was maintained by some, that the germ of every living being contains within itself the whole of the force necessary to accomplish the organization of its fabric, and to impart to each portion of it the peculiar powers with which it is endowed: an obvious objection to which doctrine is, that, if this be true, not only must the germ contain the whole vital force of the fabric into which it is evolved, but also that which it imparts to its descendants; so that the first individual of a race must have concentrated within itself the vital force of its entire posterity,—a palpable *reductio ad absurdum.* To escape from this difficulty, it has been alleged that the vital force with which matter becomes endowed by the process of organization, previously existed in it in a *latent* or *dormant* state, and is made *sensible* when the nutrient matter is incorporated into a living fabric. This doctrine could claim no higher value than that of a mere hypothesis; and it rested on

* See Mr. Simon's "Lectures on General Pathology," pp. 87, 152; and Mr. Paget's 'Lectures on Inflammation,' in "Medical Gazette," 1851, vol. xlv. p. 92.

the idea that latent or dormant force of other kinds (such as Heat) had a real existence,—an idea of which a more logical appreciation of the facts of science has completely exposed the fallacy. For it is now coming to be generally acknowledged, that all force must (from its very nature) be *active* in some mode or other; that force can neither originate *de novo*, nor cease to be operative under some form; and that in every case in which force *seems* to be annihilated, it merely changes its *modus operandi*. Thus, when Motion is retarded by friction, Heat is generated, with Electricity in addition whenever the rubbing surfaces are otherwise than perfectly homogeneous; so when Heat is caused to vaporize water, it no longer manifests itself *as* Heat, but in the form of mechanical power which produces Motion; and the discharge which restores the Electric equilibrium, is in like manner attended with the development of Mechanical force. It will be found that, in all instances in which such a conversion or metamorphosis of force takes place, some *material substratum* is required as its instrument. This may be, in some cases, of almost any description whatever; as when Heat is produced by the friction (or retarded motion) of solids, liquids, or even gases; or when Motion (as shown in expansion) is produced by the application of heat to any kind of material substance. But in other cases, the change can only be effected through some *special* kind of instrument; or, if several substances may serve as its medium, there is some one which is greatly superior to every other, in the readiness with which a certain force manifests itself through it. Thus, iron is the substance through which an Electric current can best develope Magnetic force; a combination of bismuth and antimony is that through which Heat can best generate Electricity; and the affection of Light by Magnetism, though producible through any transparent medium (but not through a vacuum), can be made much more obvious when the magnetism is made to act upon a glass composed of vitrified borate of lead, than through the medium of any other substance yet known. It is, indeed, on this *speciality* in the action of different substances, when subjected to the influence of the same forces, that our notion of their *properties* entirely rests;—and to say that all matter which is capable of becoming organized possesses 'vital properties,' is merely to affirm in other words, that it is capable of being made a part of a living structure, and of becoming the instrument of operating after the same fashion upon other matter,—leaving the question as to the source or origin of the force which thus changes it, or by which it induces changes in other matter, just where it was.

123. The doctrines which have been just now glanced at, as expressing the present aspect of Physical Science, whilst they indicate the fallacy of some of what have been considered the established principles of Physiology, conduct us at the same time to a new and more satisfactory solution of the problem. Looking at the phenomena of Life from the same point of view as that from which we are now taught to regard those of Physical Science,—namely, as the results or manifestations of a certain kind of force, acting through those forms of matter which we term organized,—we are further led to seek for its source, not in the organism itself, but in some power external to it. And this power we find in those Physical agencies, Light, Heat, and Electricity, which have been commonly accounted "Vital Stimuli;" their operation, either singly or in combination, having

long been recognized as necessary to enable an organized structure to manifest vital phenomena. Thus, *Light,* acting upon the living Vegetable cell, makes it the instrument of decomposing carbonic acid, water, and ammonia, and of generating organic compounds which the Chemist has not yet been able to imitate; and the amount of carbonic acid thus decomposed has been found to bear a constant ratio (*cœteris paribus*) to the illuminating power of the rays which it receives.* The agency of light, however, is chiefly exerted in preparing the pabulum to be appropriated by the organism; and we see in the germinating seed, that where this has been previously elaborated, light is not required for its conversion into living tissue. But for this purpose, a certain measure of *Heat* is required; and the rate of germination, that is, the rate at which the organizable material is converted into living tissue, is determined (within certain limits) by the degree in which that agent is in operation. In the Animal kingdom, for which, as for the germinating seed, the nutrient material is already provided by a pre-existing vegetation, the dynamical influence of Light is of comparatively little importance; but we have abundant evidence, in the life of the 'cold-blooded' tribes, which are destitute of the power of maintaining an independent temperature, that the rate of vital activity, as manifested both in the phenomena of growth and development, and in the production of nervo-muscular force, is determined (within certain limits) by the amount of *Heat* to which the individual is subjected. This dependence is no less real and immediate in the case of warm-blooded animals; but it is rendered less apparent by the uniformity of temperature which they are enabled to sustain. Of the degree in which the ordinary phenomena of Life are dependent upon *Electricity* acting upon the organism from without, we as yet know next to nothing; the mode in which they are affected by this agent not having been yet precisely determined. It can scarcely be doubted, however, from what *is* known, that it stands in very close relation to Vital force, and is capable of exerting an extremely powerful influence upon its operations.

124. It seems, then, to be a legitimate expression of the dynamical conditions requisite for the production of the phenomena which we distinguish as *Vital,* to say that they are dependent, directly or indirectly, upon the *Physical* forces pervading the Universe; which, acting through organized structure as their 'material substratum,' manifest themselves as Vital Force, one of the most characteristic operations of this being the production of new tissue, which in its turn may become the instrument of a similar metamorphosis. And we have the same kind of evidence, that Light and Heat acting upon the organic germ, become transformed into Vital force, which we possess of the conversion of Heat into Electricity by acting on a certain combination of Metals, or of Electricity into Magnetism by being passed round a bar of iron, or of Heat or Electricity into Motion when their self-repulsive action separates the particles of matter from each other. For we shall presently find, that just as Heat, Light, Chemical Affinity, &c., are transformable into Vital force, so is Vital force capable of manifesting itself in the production of Light, Heat, Electricity, Chemical Affinity, or Mechanical Motion; thus completing

* See Prof. Draper "On the Forces which produce the Organization of Plants," p. 177.

the proof of that *mutual* relationship, or 'correlation,' which has been shown to exist among the Physical and Chemical forces themselves.

125. In order, however, to arrive at a definite and complete conception of the source of Vital force in the Human Organism, it will be necessary to examine, a little more in detail, into the reciprocal relations, material and dynamical, which subsist between the Animal and Vegetable kingdoms, and between these and the Inorganic world.—The Plant, when acted-on by Light, forms certain organic compounds, at the expense of the water, carbonic acid, and ammonia of the soil and atmosphere, decomposing these binary compounds into their four elements, and uniting these again into ternary and quaternary combinations of a very peculiar character; and the Light, by whose agency alone this process can be effected, may be considered as metamorphosed into the peculiar *affinity*, or chemical force, by which the elements of these compounds are held together.* The pabulum thus generated is applied by the Vegetable organism to the extension of its own structure, the vital force requisite for this purpose being sustained by Heat acting *ab externo;* and thus the fabric may be augmented to an almost unlimited extent, every increase of surface affording a new instrument for the agency of light, and thus affording the conditions requisite for the production of an additional amount of organic compounds. The whole *nisus* of vegetable life may be considered as manifesting itself in this production; and, in effecting it, each organism is not only drawing *material*, but *force*, from the universe around it. Supposing that no Animals existed to consume these organic compounds, they would be all at last restored back to the inorganic condition by spontaneous decay, which would reproduce the water, carbonic acid, and ammonia, from which they were at first generated. In this decay, however slow, light and heat would be given out, in the same amount as when more evidently produced in the ordinary combustive process; and we do in fact observe, that, during certain phases of vegetation (namely, germination and flowering) a sensible amount of Heat is produced by many plants as one of the ordinary phenomena of their lives, Light also being occasionally manifested.† Moreover, spontaneous movements are sometimes to be observed in Plants, under circumstances which indicate that they are to be considered as manifestations or expressions of Vital force; and thus the Vegetable, even during its life, may restore to the Universe some portion of the forces which it has derived from it under other forms. It is only, however, when the complete conversion of the organic compounds it has formed, into the binary compounds which furnished their materials, has taken place, that the Plant can be considered as having wholly given back the forces which it consumed in their first production; and this period may be almost indefinitely postponed by the preservation of these substances; so that in fact it is only now, that Man, whilst consuming the stores of Coal, which have been prepared for his use by the luxuriant Flora of past ages, is reproducing and applying to his own pur-

* That Light, or some component of it, ceases to exist *as such*, when it thus operates upon living Vegetable surfaces, is shown by the curious fact, that such surfaces are always represented in Photographic pictures as if they were *black*, that is, as if they received or reflected no light at all; hence these pictures can be made to afford much more faithful representations of buildings, figures, &c. than they can do of the ordinary face of Nature.

† See "Prin. of Phys., Gen. and Comp." §§ 607, 616.

poses the Light and Heat which sustained the vegetable life of the Carboniferous period, whilst returning to the atmosphere the water, carbonic acid, and ammonia, which were then withdrawn from it.

126. But the Organic Compounds which the agency of Light and Heat upon the Vegetable fabric has produced, are designed for a much higher purpose than that of being merely given back to the Inorganic universe by decay or combustion; and the forces which hold together their elements have a much more exalted destiny. In serving as the food of Animals, a part of these compounds become the materials of their organized tissues, and the instruments by which their various forms of Vital power are exercised; and in the greater number of Animals, as in the germinating seed, the Heat which is supplied from without may be looked upon as the ultimate source of the power by which the organizing process is carried on.—Thus, during the whole period of growth and development, there is, as in the Plant, a continual augmentation in the amount of Vital action performed; and the increase of this would be unlimited, were it not checked by a process of a converse character. For the peculiar activity of Animals consists, not in the phenomena of vegetative growth, but in the performance of movements, through the instrumentality of the nervo-muscular apparatus, which is built up by the organizing process; and the execution of these movements involves an *expenditure* of Vital force, as manifested in the death and disintegration of the nervo-muscular tissues, which appears to be in strict relation to the amount of Physical power thus generated. And thus it happens, that there is, during Animal life, a continual restoration to the Inorganic world, of the water, carbonic acid, and ammonia, originally supplied by it as the food of plants; these being formed by the union of the oxygen of the atmosphere (which was not appropriated by the plant) with the elements of the nervo-muscular tissue, or rather with those of urea, lactic acid, &c., which are the immediate products of their decay (§ 91). Not only is Motion thus generated, but also Heat, and (occasionally) Light and Electricity; and thus an Animal which has arrived at its full growth, and which is simply maintaining the standard it has then acquired, is continually restoring to the Inorganic world both the *material* equivalents of its food, and the *dynamical* equivalents of the Chemical affinities which held together the elements of this, as well as of the Heat which supplied the organizing force whereby it was converted into living tissue. The final decay of the organism, as in the Plant, will give back both the material and dynamical equivalents of the matter and force which were consumed in its first production, unless its substance should be appropriated as food by another organism; in which case it serves to the Carnivorous animal precisely the same purposes, as those to which the organic compounds supplied by the Plant are subservient in the Herbivorous animal.

127. The condition of Man and of all 'warm-blooded' animals, however, differs in this important particular from that of 'cold-blooded' animals, and of plants. For whilst the latter are almost entirely dependent for the Heat which is the source of their vital force, upon that which they receive from the solar rays, so that their temperature rises and falls with that of the medium they inhabit, the former are enabled to maintain the heat of their bodies at a constant standard, by combustive processes which take place in their interior, at the expense, not only of the mate-

rials of their disintegrated tissues, but also of a portion of their food, the non-azotized ingredients of which are chiefly appropriated to this purpose (§§ 42, 50). And thus we find that whilst the Azotized compounds prepared by Plants supply the actual *materials* for the building-up of the Animal fabric, the Hydro-carbonaceous or non-azotized (starchy, saccharine, oleaginous, &c.), answer the not less important purpose of furnishing, by their restoration to their original condition, the chief *dynamical* agency, which, acting through the previously-formed organic structure, enables it to appropriate the former, and thus to supply the conditions needed for the production of nervo-muscular power, the development of which may be considered as the great end and aim of Animal existence. And it is a very interesting exemplification of the correctness of these views, that the rate of recurrence of those 'periodical phenomena' of various kinds, which mark the progress of vital activity, should be almost entirely dependent among cold-blooded animals upon external influences, so that they may be artificially accelerated by warmth and retarded by cold; whereas, in warm-blooded animals, their recurrence is far more regular, the rate of their vital activity being kept at a much more uniform standard, in virtue of their fixed temperature.*

### 3. *General Survey of the Life of Man.*

128. It will be advantageous, before proceeding further, to apply the doctrines which it has been the purpose of the preceding section to point out and illustrate, to the history of Human Life, considered under its most general aspect.—The *germ* of the Human organism, derived from the vital operations of its parents, must be considered as possessing a *property* or *capacity*, whereby, when it is placed in the requisite material conditions, and subjected to a certain dynamical agency, it evolves itself into the complete fabric, which is subsequently maintained by the continuance of the same agencies. And this *property* is so far peculiar, that the germ of Man can never be evolved into any other form than the Human, although it may attain this but very imperfectly. It is, however, a purely *passive* capacity; and the germ must be acted-on by a force external to it, before it can advance a single step in the developmental process. This force is Heat, which, being supplied by the parental organism, is converted by the instrumentality of the germ into the Vital force, whereby it appropriates the nutrient materials supplied to it, and converts these into living tissue.† These nutrient materials, prepared by the parent, are stored up in the ovum in sufficient quantity to serve for

* See, on the subject of the preceding Section, the Author's Memoir 'On the Mutual Relations of the Vital and Physical Forces,' in the "Philosophical Transactions" for 1850; Mr. Newport's paper 'On the Reciprocal Relations of the Vital and Physical Forces,' in the "Annals of Natural History," Nov. 1850; and Dr. J. R. Mayer's Treatise "Die organische Bewegung in ihrem Zusemmenhange met dem stoffwechsel," Heilbronn, 1835.

† This is seen obviously enough in the incubation of Birds, in which the contact of the surface of the body imparts that heat to the germ, which it derives in Mammals from the textures wherein it is imbedded. It is curious to observe that in several cold-blooded animals, there is a special provision for generating heat, when the developmental processes are being actively carried on; as in the maturation of the pupæ of Bees, and the evolution of the embryo within the egg in certain viviparous Reptiles. See "Prin. of Phys., Gen. and Comp.," §§ 623 and 725.

the early development of the embryo, until it can obtain them from other sources; but while their quantity is adequate, in the Oviparous animal, to serve for the evolution of its fabric into such a degree of completeness, as enables it to ingest and appropriate its further supplies for itself, it suffices in the Mammal for little else than to enable the germ to evolve an apparatus, whereby it may receive a continued supply more directly imparted to it from the blood-vessels of the mother. The first step in the process of evolution consists in mere *growth*, that is, in the multiplication of cells by duplicative subdivision, without any departure from the primitive type; but gradually we see indications of *development*, in the multiplication of cells in particular directions, whereby the foundation is laid of the principal *organs* of the fabric, and in the metamorphoses of certain of them into the *tissues* which are characteristic of the perfect organism; and it is in these two particulars alone, that the later stages of embryonic life essentially differ from the earlier. During all this time, Heat is being continually supplied by the parent and appropriated by the embryo; which, at its period of maturity, exhibits the result of the continued operation of the organizing force, and of its action, through the instrumentality of the germ (in the first place) and (subsequently) of the living fabric that has had its origin in it, upon the nutrient materials with which it has been supplied.—Up to this time, there has been very little expenditure of Vital force in anything else than the formation of tissue; for the life of the embryo is one rather of *organic* or vegetative, than of *animal* activity; the action of the heart, and the occasional reflex movements of the limbs, being its only manifestations of nervo-muscular power. And thus it seems to be, that the formative capacity is greater during embryonic life, than at any subsequent period, and greater in its earlier than in its later stages; so that we have not only evidence of an extraordinary power of regenerating parts which have been lost by disease or accident, as shown in attempts at the reproduction of entire limbs after their 'spontaneous amputation;' but there is also not unfrequently an absolute excess of productive power, as shown in the development of supernumerary organs, which may even proceed to the extent of the complete duplication of the entire body, by the early subdivision of the embryonic structure into two independent halves. (See CHAP. XIX., SECT. 4.)

129. From the time of its entrance into the world, however, the condition of the Human infant is essentially changed. It is no longer supplied with nutriment by the direct transmission of organizable materials from the circulating fluid of the mother to its own; but obtains it by the processes of digestion, absorption, and assimilation, which involve a certain expenditure of vital force in the performance of the chemical and vital changes in which these processes consist. Thus the secretion of the gastric, biliary, and pancreatic fluids is a truly vital process, although the action of these fluids upon the alimentary materials may be purely chemical; so, again, although part of the process of absorption is effected by purely physical agencies, another part involves the development and active agency of cells, and thus occasions a demand for vital force; and the further preparation of the absorbed materials for the purposes of nutrition, seems also to require an expenditure of that which, for the sake of convenience, we have termed the 'cell-force.' Thus, then, even as regards these preliminary operations, the infant is placed in a very

different condition from the intra-uterine embryo; and in order that the change may not be too sudden, the nutriment provided by Nature for the early period of infantile life, is such as to occasion the least possible demand upon its vital powers for the preparation of the organizable material which is required for its further growth and development. But the transition is a most important one in another particular; the infant is now thrown in great degree upon its own resources for the generation of its heat; and this it is enabled to accomplish by the combustion of a portion of its food which is specially provided for the purpose, this combustion being promoted by the arrangements for that active respiration which now supersedes the very limited aeration of its circulating fluids that was sufficient during fœtal life. Now in the movements of the respiratory muscles and of the walls of the alimentary canal, we have a new source of expenditure of vital force, and of destruction of tissue; and this expenditure is progressively augmented, as the motions of the body and limbs become increasingly active. Thus we find that the formative powers are not exercised during childhood and youth, solely in the *construction* and *augmentation* of the fabric (as they were during embryonic life), since there is a constant demand upon them for its *maintenance;* and this demand becomes greater and greater, in proportion to the exercise of the Animal powers.

130. At the same time there appears to be a progressive reduction in the 'germinal capacity;' for not only is there to be observed a diminishing aptitude for the production of new parts (as shown, for example, in the cessation of the production of new tooth-sacs by gemmation from the old, the last operation of this kind being that by which the 'dentes sapientiæ' are originated, § 285), but we also perceive a decrease in the power of repairing the ravages which disease or injury may have made in the organism as previously formed. Still, however, this capacity manifests itself in a very remarkable manner during the whole period of growth; being most obviously displayed in the complete evolution of the generative apparatus, the condition of which was previously rudimentary; but being in reality yet more remarkably exhibited in the various acts by which the type or pattern of the organism is maintained and completed, notwithstanding the various influences tending to its degradation. For it must be borne in mind, that the *growth* of the body of Man, or of that of any of the higher Animals, takes place in a manner essentially different from that of the Vegetable fabric; the latter mainly consisting in *addition to the parts already formed,* whilst the former is effected by a continual *development of new structure in place of the old.* Thus in the Tree we observe, year by year, the same trunk, the same branches, the same roots; and the only difference which we notice between the young tree and the old one, consists in the increased thickness of the original stem and of its ramifications, which is shown by a tranverse section to depend entirely upon the enclosure of the original in new layers of wood progressively developed around it, and in the greater number and extent of the smaller twigs and rootlets, which are put forth, year by year, from the larger. When we compare, on the other hand, a single limb of the adult man with that of the infant, we find that the position of every part of it has changed. The same bones, muscles, tendons, ligaments, blood-vessels, nerves, &c., are recognizable in both cases; and maintain,

with little variation, the same *relative* positions. But the bone has swollen, as it were, in every direction, so that its very cavity is now of absolutely larger diameter than the entire shaft of the bone of the infant, whilst the whole length of the latter would constitute but a fraction of the distance that now intervenes between its extremities. With the enlargement of the bone, the points of muscular attachment are of course separated from each other; and the muscles themselves undergo a similar augmentation, as do likewise all the soft tissues connected with them; these seeming, like the bone, to have swollen by a process of interstitial growth, rather than to have simply received additions to their surface and extremities. Now it will be shown hereafter (§ 267), that this enlargement is effected, in the case of the Bone, not by a mere superficial addition (such as that which causes the shell of the Echinus to swell from the size of the head of a pin to that of the head of a child, the new matter being developed at the edges of the numerous polygonal plates of which it is composed), but by a combination of the processes of *absorption* and of *deposition*; or rather, in fact, by the continual progress of *degeneration* and *death*, consentaneously with every new production of living organized tissue. And what is true of the bone is true also, there is good reason to believe, of the Muscles and all the softer organs, the normal duration of whose individual parts is naturally less; so that their enlargement seems essentially to consist in the excess of production over the disintegration which is continually taking place in them, this disintegration (as shown by the amount of the urea, carbonic acid, &c., which are excreted) being far more rapid during the period of growth, than it is in the subsequent stages of life.

131. That the germinal capacity, though inferior to that of the embryo, still persists in a high degree during the period of childhood and youth, is further shown in the readiness with which the effects of injuries and disease are recovered from; for although the regeneration of lost parts does not take place to nearly the same extent as during early embryonic life, yet, up to a certain point, it is effected with great completeness, and with much greater rapidity than at later epochs. It is still, in fact, rather in the exercise of formative power, than in the production of nervo-muscular vigour, that the vital force of this period is displayed; and we may readily trace such a relation of reciprocity between these two modes of its manifestation, as is strongly indicative of the community of their source. For it is familiar to every observer, that, when the growth of a child or a young person is peculiarly quick, its nervo-muscular energy is usually feeble, and its power of endurance brief, in comparison with that which can be put forth by one whose frame is undergoing less rapid increase. And we observe, moreover, that the capacity of resistance to depressing influences of various kinds, which is a no less decided manifestation of the vital power of the organism (seeing that these influences are of a kind which *tend towards* its death), is possessed by the latter in a far higher degree than by the former.—Under one form or the other, however, we must recognize the existence of a high degree of vital power during the period of childhood and adolescence; and this power is sustained by the large consumption of food; for this affords not merely the *materials* largely required for the construction of the fabric (which may be said to be in continual progress of pulling-down and rebuilding, all the old

materials being carried away as useless), but also those which serve for the maintenance of the heat of the body, and which thus supply the *force* which is requisite for the sustentation of its activity. The human infant at first possesses but a feeble heat-producing power; and the lower the temperature to which it is exposed, the more does it depend upon some external source of warmth. As its digestive capacity improves, however, and it can appropriate an adequate supply of food, its calorific power augments; for its rapid circulation and active respiration enable the combustive process to be performed with an energy greatly surpassing that which is displayed in later life, as is shown in the quantity of carbonic acid thrown off. And thus, as it is from its food that the organism derives not merely its materials but its vital force, and as the expenditure of both is peculiarly rapid, it comes to pass that the dependence of life upon a continual supply of food is far more close at this period than subsequently; so that when children and adults are subjected at the same time to complete or partial starvation, the former succumb much earlier than the latter.

132. The period of *adult age* is marked by an increase alike in the nervo-muscular power of the body, and in its general vigour and endurance; the augmentation of the latter being most strongly displayed in the activity of the generative function. Still it cannot be said that its vital force is on the whole increased in proportion to its bulk; for the formative power is decidedly diminished. The production of new tissue is now for the most part limited to the replacement of that which has become effete by use; there is no longer a capacity for the production of new organs, and comparatively little for the augmentation of those already existing; the increase of the uterine and mammary structures, during the period of gestation, being the most important examples of formative power, and these presenting themselves in the sex in which there is least of nervo-muscular activity and of general vigour. We should infer, then, that the 'germinal capacity' is now on the decline; and this further appears from the inferior energy and completeness with which the reparative processes are performed, as compared with the mode in which they are executed during the period of growth. Moreover, the ordinary rate of *waste* or *degeneration* of tissue is now much less rapid than during the period of growth; for we have seen that decay and removal, in the latter case, are among the very conditions of increase; whilst in the former, they proceed, for the most part, only from the expenditure of the vital powers of the tissues, consequent upon their functional activity.—The whole *nisus* of development, in fact, during this period, appears to be directed towards the *maintenance* of the organism in the state which it had acquired at its commencement, by the regeneration of its tissues as fast as they undergo disintegration, and by the renovation of its vital force in proportion as this is expended. There is consequently a less demand for alimentary material, than during the previous periods (allowance being made for the augmented bulk of the body); the proportional amount of heat produced (as indicated by the carbonic acid exhaled) is also less; and the dependence of life upon a constant supply of aliment is far less close.

133. The *decline of life* exhibits a much more obvious diminution of the whole vital power of the organism; for not only is its formative activity now greatly reduced, but its nervo-muscular energy and general vigour progressively diminish, and its generative power declines or ceases

entirely. Of this diminution in formative power, we have evidence in the entire absence of any attempt at new development, in the less perfect and more tedious manner in which the losses of substance occasioned by disease or injury are recovered from, and in the gradual degeneration of the organism in general. The tissues which are rendered effete by their functional activity, are not any longer replaced in their normal completeness; for either the quantity of new tissue is inadequate, so that the bulk of the organs is obviously reduced; or their quality is rendered imperfect, by the production of structures in various phases of degeneration (especially the fatty), in place of those which had been previously developed in the fullest completeness. The inferiority of nervo-muscular energy and of general vigour are thus evidently the result of the deficiency, and not (as in the period of growth) of the excess, of formative power; and in proportion as the 'waste' of the tissues consequent upon their functional activity, is more rapid than their renovation, a progressive diminution must take place. It is obvious that the cause of this decline must lie within the organism itself; since, the external conditions remaining the same, the same amount of vital activity is no longer manifested; and we can scarcely attribute it to any other source, than a gradual decline in the 'germinal capacity,' which seems to set a limit to the life of the entire organism, as it does to that of the single cell. For, when neither disease nor accident shortens what may be considered the normal term of life, there is a gradual diminution in every kind of vital activity, until it entirely ceases; the formative power seems progressively to exhaust itself, until no assistance from artificial heat, no supply of the most nutritious food, can any longer avail for the generation of new tissue; and the nervo-muscular energy gradually declines, until at last even those actions on which the circulation and respiration entirely depend can no longer be performed, and with the cessation of these functions the life of the entire organism becomes extinct.—Such we may consider to be the mode in which *Death* normally occurs. Various abnormal influences, however, may bring about this final result, at an earlier period, and in different modes; these will be considered on a future occasion (CHAP. XXI.).

## CHAPTER IV.

### OF THE BLOOD; ITS PHYSICAL CHARACTERS, CHEMICAL COMPOSITION, AND VITAL PROPERTIES.

#### 1. *General Considerations.*

134. IN the organism of Man, as in that of all the higher Animals, the materials for the nutrition of every portion of the structure are supplied by the *Blood*, which, itself formed at the expense of the organic and inorganic constituents of the Food, is constantly circulating through the vessels during the whole of life; and each tissue possesses the power of drawing from this liquid, and of appropriating to its own use, the particular components of its substance, which either pre-exist as such in the blood, or are capable of being readily formed from it by a process of

chemical transformation. The supply of these materials, however, is by no means the sole purpose of the Circulation of the Blood; for it also furnishes the means of removing the effete particles which are set free by the disintegration of the tissues; these being drawn into the current, probably at the very time when the components of the newly-forming structures are given forth, and being conveyed by it to the various organs which are provided for their elimination. Hence the Blood not only contains the materials for the renovation of the tissues, but also the products of their decay: but there is an important difference in the proportion of these two sets of components; for whilst the former make up the principal part of the mass of the fluid, the latter are only detectable in it with difficulty, so long as the excretory organs maintain their normal activity; and only make their presence obvious, when they accumulate unduly, in consequence of the retardation or suspension of the eliminating operations.—But besides thus meeting the demand occasioned by the *constructive* operations, and preventing the results of the *destructive* from exerting an injurious influence on the system, the Circulation of the Blood serves the important purpose of introducing Oxygen from the atmosphere, the presence of which appears to be an essential condition of the peculiar vital activity of the Nervous and Muscular tissues, whilst it is also required in various other metamorphoses which form part both of the constructive and of the destructive operations; and just as the circulating current takes up, and carries to their appropriate outlets, the various excretory matters which are set free in the course of its nutrient operations, so does it also imbibe the Carbonic acid, which is one of the chief products of the action of oxygen upon the tissues and fluids of the body, and convey this to the lungs and skin for elimination. This product is continually being formed in such large amount, that its presence in the blood can always be readily demonstrated; and if its elimination be checked for even a few minutes, it accumulates to such an extent as to occasion the immediate destruction of life.—But besides the Histogenetic materials and Oxygen, on the one hand, and the various products of the disintegration of the tissues on the other, the blood contains those non-azotized substances which are received into it for the purpose of supplying the *pabulum* of the combustive process; and the union of their elements with oxygen introduced from the atmosphere, which is continually going on, becomes an additional source of the production of carbonic acid, and of its injurious accumulation if its elimination be checked.

135. From the variety of operations to which the Blood is subservient, it naturally follows that the changes which it undergoes in different parts of its circulation are of a very diversified nature, and that the composition of the fluid in the several parts of its course will be far from uniform. Between the blood which is being distributed by the Systemic arteries to the body at large, and that which is being collected from it again by the systemic veins, after having percolated the tissues, there is not only an obvious difference in hue, which indicates an important change, but there is also a considerable difference in composition, which is revealed by chemical analysis: and a difference of a converse nature presents itself, between the blood that is on its way to be distributed to the Lungs, and that which is returning from them. So, again, although there is no obvious dissimilarity in physical characters between the blood which is

transmitted to the Liver by the vena portæ, and that which is carried off from it by the hepatic vein, yet chemical analysis reveals a very remarkable difference in their composition, and shows that the blood of the ascending vena cava (above the entrance of the hepatic vein), that of the right cavities of the heart, and that of the pulmonary artery, differs from all other blood in the body, in containing an appreciable quantity of sugar (§ 45). In many other cases, we know that an important difference *must* exist, although chemical analysis has not yet detected it; thus, the blood of the Renal vein must be more free from the components of the urinary excretion, than that of the renal artery which conveys them to the kidney; whilst the blood of the systemic veins in general must contain them in greater amount than their corresponding arteries, since they are discharged into the current during its passage through the tissues, of whose disintegration they are among the products.—In the account to be presently given of the Blood, those most general characters and properties will be first described, which it presents in all parts of its circulation; the principal differences which have been substantiated in the composition of the blood in the several portions of its circuit, will then be noticed; and, lastly, some account will be given of the most important of those pathological alterations which it exhibits in disease.

136. The precise determination of the *quantity* of Blood contained in the body, is more difficult than might have been at first supposed; and the estimates which have been made of it, have been most strangely discrepant. The entire amount which flows from a large arterial trunk freely opened, can by no means be taken as a measure; since, however freely it may be permitted to escape, a considerable quantity still remains within the blood-vessels, especially if the heart's action fail before the loss of blood has proceeded very far, so that it is not drawn from the venous system. A closer approximation may be made by opening several vessels at once, which was the method adopted by Herbst;* who estimated the proportion of the weight of the blood to that of the entire body to be as 1 : 12 in the Ox, as 1 : 16 in the Dog, as 1 : 18 in the Horse, as 1 : 20 in the Goat, Calf, Lamb, and Hare, as 1 : 22 in the Sheep and Cat, and as 1 : 24 in the Rabbit. With these estimates, the conclusions drawn by Vanner, from his recent observations in the *abattoirs* of Paris, pretty closely correspond; for he is led by them to the belief, that for horned cattle in general, the proportion does not vary far from 1 : 20.† It is obvious, however, that no such method can give more than a *minimum;* since, even after the most complete exsanguination that the freest opening of the vessels can permit, a considerable quantity of blood is still retained in them, and especially in those of the head. And there are various observations which lead to the belief, that such estimates are far too low as regards Man; since it appears that a quantity of blood equal to at least one-tenth of the weight of his body, may be poured forth from his vessels within a short time. Still, occurrences of this kind, of which Haller has brought together an interesting collection,‡ afford but an unsafe basis for our estimate; since it is necessary to allow for the fact, that when the vessels are becoming emptied of blood, a transudation of

* "De Sanguinis quantitate, qualis homini adulto et sano convenit." Gœttingæ, 1822.
† "Comptes Rendus," tom. xxviii. p. 649.
‡ "Elementa Physiologiæ," vol. ii. pp. 3, 4.

fluid takes place *into* them from the surrounding tissues, as is evidenced by the diminution in the specific gravity, and in the increase in the proportion of water, which are apparent when even the first and last parts of the blood drawn at an ordinary venesection are compared (§ 162): so that, if the hæmorrhage be going on for some hours, a much larger quantity of fluid may be poured forth from the vessels, than was ever contained within them at any one time; and if liquids be ingested during its continuance, a portion of these, being at once received into the circulating current, will go to augment the amount which escapes from it. Two remarkable instances of this kind are cited by Burdach* from Wrisberg; who states that a female who died from violent metrorrhagia lost 26 lbs. of blood, and that 24 lbs. were collected from the body of a plethoric female who had suffered death by decapitation. In the first of these cases, it is probable that, as death could not have been *immediate*, some increase took place from the fluids of the body; in the second, however, the suddenness of the discharge of blood, and its concurrence with the destruction of life, must have prevented any considerable augmentation from this source; and if any such increase did take place, it probably did not exceed the amount of blood remaining undischarged in the vessels.—Another mode of determining the total amount of the circulating blood has been proposed by Prof. Valentin;† who first draws a sample of blood from an animal, and ascertains the proportion of water which it contains, then injects a determinate quantity of water into the vessels, and immediately draws fresh samples from different parts of the body, in which also he ascertains the proportion of the solid to the fluid components; and from the amount of dilution which the last-drawn blood exhibits, as compared with the first sample, he calculates the whole bulk of the circulating fluid. From these data, Prof. Valentin estimated the proportion of blood in the Dog as $1:4\frac{1}{2}$, and in the Sheep as $1:5$; so that, applying the former of these proportions to the Human body, a man weighing 145 lbs. would have 32 lbs. of blood, and a woman weighing 127 lbs. would have 27 lbs. of blood. It can scarcely be doubted that this statement is too high; and it is not difficult to discern an important fallacy in the method on which it was based. For however rapidly the operation may be performed, some portion of the water injected will transude from the vessels into the surrounding tissues, and will escape by the kidneys; and thus, the degree of its dilution being diminished, the estimate of the total amount of the blood will be raised considerably above the reality.—It has been more recently proposed by more than one experimenter, to inject, in place of water, some saline compound, whose presence in the blood might easily be determined quantitively, and which should neither be so poisonous as to produce speedy death, nor be capable of such rapid transudation as to escape too readily into the tissues or the urine. The sulphate of alumina has been employed for this purpose by Prof. Blake‡ (of St. Louis, U. S.); and his experiments lead to the conclusion that the proportion of blood in the body of a Dog is as $1:8$ or $1:9$; so that, applying the same proportion to Man, the quantity of blood in a Human body weighing 144 lbs. would be 16 or 18 lbs. Several circumstances

* "Traité de Physiologie," traduit par Jourdain, tom. vi. p. 119.
† "Repert. fur Anat. und Phys.," band iii. p. 281.
‡ See Prof. Dunglison's "Human Physiology," seventh edit. vol. ii. p. 102.

lead to the belief that this estimate is not far from the truth; but it cannot be doubted that a considerable variation in the relative amount of blood will exist among different individuals.

## 2. *Physical, Chemical, and Structural Characters of the Blood.*

137. The Blood, as it flows forth from an opening in a large vessel, is an apparently homogeneous liquid, possessing a slight degree of viscidity, with a consistence and density somewhat greater than that of water, but especially distinguished by its *colour*, which is usually of a bright scarlet when it is drawn from an artery, and of a dark purple, sometimes almost approaching to black, when it is drawn from a vein. This difference of colour, however, is by no means constant; for arterial blood may sometimes be unusually dark, whilst venous blood is occasionally so florid that it might almost be taken for arterial. The former condition is observable, when from any cause the respiratory process is imperfectly performed, and may be especially noticed during operations performed under the influence of anæsthetic agents; it has also been remarked by Dr. John Davy as usually characterizing the arterial blood of the inhabitants of hot climates;* but in any of these cases, the ordinary arterial hue is acquired by the blood when it has been sufficiently exposed to the air. The florid hue is presented by the venous blood of animals which are made to respire pure oxygen; but it seems normal with some individuals whose respiration is peculiarly active.—The *specific gravity* of the Blood is stated by Nasse,† as the result of numerous observations, to vary (within the limits of health) between 1050 and 1059; the average being taken as 1055. The principal source of this variation, is the want of constancy in the proportion of the red corpuscles in the blood; for the specific gravity of these, when separately examined, is found to be as high as 1088·5, whilst that of the liquid in which they float is no more than 1028; and hence the specific gravity of the blood of men is usually higher than that of women (§ 159), and that of the portion of blood first drawn exceeds that of the portion which flows last (§ 162).—The chemical reaction of the Blood seems to be invariably *alkaline;* and very important purposes are served by this alkalinity (§§ 83, 84).—When we add that the Blood has a saltish taste, and a faint odour resembling that of the pulmonary and cutaneous exhalations of the animal from which it is drawn, we have enumerated all the characteristics which can be made out by the unassisted senses.

138. When the Blood is examined with the Microscope, however, either immediately upon being drawn, or whilst it is yet circulating in the vessels of the living body (as in the foot of the Frog, the wing of the Bat, or any other membranous expansion of similar transparency), it is seen that its apparent homogeneity is not real, but that it consists of two very different components. These are, a transparent and perfectly colourless liquid, which is known as the *Liquor Sanguinis,* and a set of *Corpuscles,* which are suspended in it: the great mass of these last present a distinctly *red* hue, and it is to their presence alone that the colour of the blood is due; but there are also to be seen, scattered among the red, a few

* "Anatomical and Physiological Researches," vol. ii. p. 140.

† Wagner's "Handwörterbuch der Physiologie," '*Blut,*' band i. p. 82.

which are *colourless*, and which differ from the red in some other particulars presently to be noticed.—On the other hand, when the Blood has been drawn from the body, and is allowed to remain at rest, it undergoes a spontaneous coagulation, in the course of which it separates into a red *Crassamentum* and a nearly colourless *Serum*. The 'crassamentum' or 'clot' is composed of a network of Fibrin (§§ 26, 27), in the meshes of which the Corpuscles, both red and colourless, are involved, together with a certain amount of serous fluid. The 'serum,' which is the same with the 'liquor sanguinis' deprived of its Fibrin, coagulates by heat, and is therefore known to contain Albumen; and if it be exposed to a high temperature, sufficient to decompose the animal matter, a considerable amount of earthy and alkaline Salts remains.—Thus we have four principal components in the Blood; namely, *Fibrin, Albumen, Corpuscles*, and *Saline matter*. In the circulating blood, they are thus combined:—

$$\left.\begin{array}{l}\text{Fibrin}\\ \text{Albumen}\\ \text{Salts}\end{array}\right\}\ \text{In solution, forming Liquor Sanguinis.}$$

Corpuscles,—suspended in Liquor Sanguinis.

But in coagulated blood, they are combined as follows:—

$$\left.\begin{array}{l}\text{Fibrin}\\ \text{Corpuscles}\end{array}\right\}\ \text{Forming Crassamentum or Clot.}$$

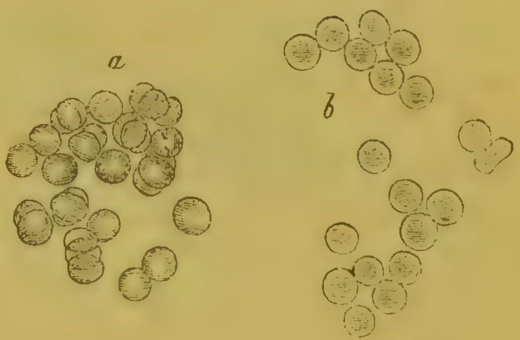
$$\left.\begin{array}{l}\text{Albumen}\\ \text{Salts}\end{array}\right\}\ \text{Remaining in solution, forming Serum.}$$

The change from the one condition to the other is due to the fibrillation of the Fibrin, which usually takes place so speedily as to involve the Corpuscles floating in the 'liquor sanguinis' before they have time to subside, although, under various conditions hereafter to be described (SECT. 3), it may occur in such a manner, that the clot, or a portion of it, is left colourless.—The Fibrin, Albumen, and Saline components of the Blood present no other characters than those which have been already detailed in the general account of these substances (CHAP. II.); and the only constituents remaining to be described, therefore, are the Corpuscular, which are not mere organic compounds, but have a regularly organized structure.

139. The *Red Corpuscles* of the Blood (commonly, but erroneously, termed 'globules') are *cells* of a flattened or discoidal form, which, in Man, as in most of the Mammalia, have a distinctly circular outline. In the discs of Human blood, when this is examined in its natural condition, the sides are somewhat concave; and there is a bright spot in the centre, which has been regarded by many as indicating the existence of a nucleus; though it is really nothing else than an effect of refraction, and may be exchanged for a dark one by slightly altering the focus of the Microscope (Fig. 10). The form of the disc is very much altered by various reagents; for the membrane which composes its exterior, or cell-wall, is readily permeable by liquids: so as to admit of their passage, according to the laws of Endosmose, either inwards or outwards, as the relative density of the contents of the cell and of the surrounding fluid may direct. Thus, if the Red Corpuscles be treated with water, or with a solution of sugar, albumen, or salt, which is of less density than the liquor sanguinis, there is a passage of this liquid into the cell; the

disc first becomes flat, and then double-convex, so that the central spot disappears; and by a continuance of the same process, it at last becomes globular, and finally bursts, the cell-wall giving way, and allowing the diffusion of its contents through the surrounding liquid. If, on the other hand, the Red Corpuscles be treated with a thick syrup or with a solution of albumen or of salt, they will be more or less completely emptied, and caused to assume a shrunken appearance; the first effect of the process being to increase the concavity, and to render the central spot more distinct.* It is probable that the Blood-corpuscles, even whilst they are circulating in the living vessels, are liable to alterations of this kind, from variations in the density of the fluid in which they float; and that such alterations may be constantly connected with certain disordered states of the system.† Thus, even without such an alteration in the Blood as would constitute disease, its proportion of water may be temporarily so much diminished by diuresis or excessive perspiration, unbalanced by a corresponding ingestion of liquid, that the corpuscles may be made to present a granulated edge; which is rendered smooth again by the dilution of the liquor sanguinis with water. We hence see the necessity, in examining the Blood microscopically, for employing a fluid for its dilution, that shall be as nearly as possible of the same character with its ordinary 'liquor sanguinis.'‡ — Microscopic observers were formerly divided upon the question, whether or not the Red Corpuscles of the blood of Man and other Mammalia contain a *nucleus;* but of late there has been a general accordance in the statement, that, in the *fully formed* discs, no nucleus is discoverable, although it may be sometimes seen in cells whose formation seems to be incomplete; and from the observations of Mr. Paget and of Mr. Wharton Jones, it would seem that we are to regard the absence of nucleus as marking a more advanced stage of development, than that which obtains in the blood-corpuscles of the lower Vertebrata, or in the early condition of those of the highest (§§ 150, 151).

Fig. 10.




Red Corpuscles of *Human* Blood; represented at *a*, as they are seen when rather beyond the focus of the microscope; and at *b* as they appear when within the focus. Magnified 400 diameters.

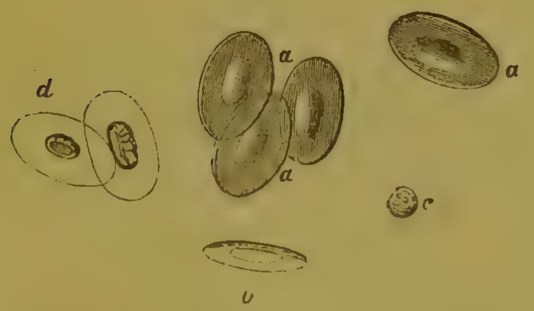
* A large number of experiments of this kind were made, and their results accurately recorded, by Hewson (see his "Inquiry into the Properties of the Blood," 1782, and his "Description of the Red Particles of the Blood," 1788), who drew from them the inference of the *vesicular* character of the Red Corpuscles. These experiments were repeated and varied by other physiologists, of whose results a table has been given by Mr. Ancell ("Lectures on the Physiology and Pathology of the Blood,' in the "Lancet," Dec. 7, 1839); but the facts stated in the text are those of most importance, and their true *rationale* seems to have been first given by Dr. G. O. Rees and Mr. S. Lane. (See their Memoir 'On the Structure of the Blood Corpuscle,' in "Guy's Hospital Reports," No. xiii.)

† See Dr. G. O. Rees's Gulstonian Lectures in the "Medical Gazette" for 1845.

‡ By Wagner, the filtered serum of frog's blood is recommended for this purpose. Weak solutions of salt or sugar, and urine, answer tolerably well; but Mr. Gulliver remarks that all addition must be avoided, when it is intended to measure the corpuscles, or to ascertain their true forms; since even the serum of one Mammal reacts injuriously on the blood of another. See "Philos. Magaz." Jan. and Feb. 1840.

140. In all Oviparous Vertebrata, without any known exception, the Red Corpuscles are oval,—the proportion between their long and their short diameters, however, being much subject to variation; and their nuclei may always be brought into view, by treatment with acetic acid, when not at first visible. In the red particles of the Frog, which are far larger than those of Man, a nucleus can be observed to project somewhat from the central portion of the oval, even during their circulation (Fig. 11, *a*, *a*); and it is brought into extreme distinctness by the action of acetic acid, which renders the remainder of the particle extremely transparent, whilst it gives increased opacity to the nucleus, which is then seen to consist of a granular substance (*d*). In the still larger blood-disc of the Proteus and Siren, this appearance is yet more distinct; the structure of the nucleus being so evident without the addition of acetic acid, that its granules can be counted.*

Fig. 11.




Red Corpuscles of *Frog's* blood; *a*, *a*, their flattened face; *b*, particle turned nearly edgeways; *c*, lymph-globule; *d*, red corpuscles altered by dilute acetic acid. Magnified 500 diameters.

141. The *form* of the Red Corpuscles is not unfrequently seen to change during their circulation; but this is generally in consequence of pressure, from the effects of which, however, they quickly recover themselves. In the capillary vessels, they sometimes become suddenly elongated, twisted, or bent, through a narrowing of the channel; and this change may take place to such a degree, as to enable the disc to pass through an aperture, which appears very minute in proportion to its diameter. When undergoing spontaneous decomposition, the blood-discs become granulated, and sometimes (as long since noticed by Hewson) even mulberry-shaped; and particles in which these changes appear to be commencing, may be found in the blood at all times.—The *size* of the blood-discs is liable to considerable variation, even in the same individual; some being met with as much as one-third larger, whilst others are one-third smaller, than the average. The diameter of the corpuscles bears no constant relation to the size of the animal, even within the limits of the same class; thus, although those of the Elephant are the largest among Mammalia (as far as is hitherto known), those of the Mouse tribe are far from being the smallest, being, in fact, more than three times the diameter of those of the Musk Deer. There is, however, as Mr. Gulliver has remarked, a more uniform relation between the size of the animal and that of its blood-discs, when the comparison is made within the limits of the same order. In Man, their diameter varies from about 1-4000th to 1-2800th of an inch, the average diameter being probably about 1-3200th; and their average thickness, according to the same excellent observer, is about 1-12,400th of an inch.†—The *colour* of the Red Corpuscles is very pale when they

* See "Penny Cyclopædia," Art. 'Siren.'

† A Tabular summary of Mr. Gulliver's very numerous and accurate measurements of the Red Corpuscles of the Blood of different animals, from all the classes and most of the orders of the Vertebrate series, is contained in the "Proceedings of the Zoological Society," No. cii., and also in his Edition of the "Works of Hewson" already referred to, published

are lying in a single stratum; and it is only when we see three or four superposed one upon another, that the full deep red tint of their contents becomes apparent. The cause of the difference in hue between the corpuscles of arterial and those of venous blood, will be considered hereafter (§ 166).

142. The principal part of the substance of the Red Corpuscles is formed by the two compounds *Globulin* and *Hœmatin*, whose distinctive characters have been already described (§§ 23, 31). That the Hæmatin is in a state of solution in the contents of these blood-cells, cannot be doubted; but as regards the condition of the Globulin there is room for more difference of opinion, some considering it to be also in a fluid state, and to form the remainder of the cell-contents, whilst others have regarded it as the constituent of the cell-walls. To the latter doctrine, however, the liberation of Globulin as well as of Hæmatin, when the Red Corpuscles are caused to burst by being treated with water (§ 139), appears a sufficient objection, the cell-walls themselves not being dis-

by the Sydenham Society (p. 237). From these, the following measurements of the blood of domestic animals (expressed in fractions of an English inch) may be selected, as the most likely to become of interest in Juridical inquiries, in which it is frequently of importance to ascertain the precise source of stains, whose sanguineous character has been determined.

| | | | |
|---|---|---|---|
| Man | 1-3200 | Pig | 1-4230 |
| Dog | 1-3532 | Ox | 1-4267 |
| Hare | 1-3560 | Red Deer | 1-4324 |
| Rabbit | 1-3607 | Cat | 1-4404 |
| Rat | 1-3754 | Horse | 1-4600 |
| Mouse | 1-3814 | Sheep | 1-5300 |
| Ass | 1-4000 | Goat | 1-6366 |

Thus it appears quite possible to distinguish the blood of all the animals enumerated, from that of Man, by the measurement of the diameter of the Red Corpuscles; those of the Dog and of the Rodents approaching his most nearly in size, whilst those of the Ruminant and Pachydermatous quadrupeds, and of the Cat, are considerably smaller.—It is important, however, to bear in mind, that the specimens of blood submitted to examination in Juridical inquiries will for the most part have been dried; and it is therefore of consequence to know the comparative dimensions of the blood-discs, after they have been submitted to this process. These are given as follows by Schmidt, in his recent work on the diagnosis of suspicious spots in criminal cases ("Die Diagnostik verdächtiger Flecke im Criminalfäller"); the measurements being expressed in decimals of a millimetre.

| | Mean. | Maximum. | Minimum. |
|---|---|---|---|
| Man | 0·0077 | 0·0080 | 0·0074 |
| Dog | 0·0070 | 0·0074 | 0·0066 |
| Rabbit | 0·0064 | 0·0070 | 0·0060 |
| Rat | 0·0064 | 0·0068 | 0·0060 |
| Pig | 0·0062 | 0·0065 | 0·0060 |
| Mouse | 0·0061 | 0·0065 | 0·0058 |
| Ox | 0·0058 | 0·0062 | 0·0054 |
| Cat | 0·0056 | 0·0060 | 0·0053 |
| Horse | 0·0057 | 0·0060 | 0·0053 |
| Sheep | 0·0045 | 0·0048 | 0·0040 |

The relative sizes of the Red Corpuscles expressed by this Table, will be seen to correspond closely with those assigned by Mr. Gulliver, in every case but that of the Pig, with regard to which there must certainly be a mistake on one side or the other.—The oval form and prominent nucleus of the Red Corpuscles of all the *oviparous* Vertebrata, enable them to be distinguished from those of Man without the slightest difficulty; consequently no question can ever lie between a stain left by the blood of a Fowl, a Turtle, or a Cod, and that left by Human blood, when the corpuscles can be distinctly made out with the assistance of the microscope.

solved; and the very large proportion which the Globulin bears to the Hæmatin is scarcely less significant.—The following is given by Prof. Lehmann (Op. cit., band II. p. 152) as the relative Chemical constitution of the Red Corpuscles and of the Liquor Sanguinis, which there is a great advantage in thus bringing into comparison.

| 1000 parts of *Red Corpuscles* contain | | 1000 parts of *Liquor Sanguinis* contain | |
|---|---|---|---|
| Water | 688·00 | Water | 902·90 |
| Solid residue | 312·00 | Solid residue | 97·10 |
| Hæmatin (including iron) | 16·75 | Fibrin | 4·05 |
| Globulin and cell membrane | 282·22 | Albumen | 78·84 |
| Fat | 2·31 | Fat | 1·72 |
| Extractive Matters | 2·60 | Extractive Matters | 3·94 |
| Mineral substances (exclusive of iron) | 8·12 | Mineral substances | 8·55 |
| Chlorine | 1·686 | Chlorine | 3·644 |
| Sulphuric acid | 0·066 | Sulphuric acid | 0·115 |
| Phosphoric acid | 1·134 | Phosphoric acid | 0·191 |
| Potassium | 3·328 | Potassium | 0·323 |
| Sodium | 1·052 | Sodium | 3·341 |
| Oxygen | 0·667 | Oxygen | 0·403 |
| Phosphate of Lime | 0·114 | Phosphate of Lime | 0·311 |
| Phosphate of Magnesia | 0·073 | Phosphate of Magnesia | 0·222 |

From this we see that not only do the Hæmatin and Globulin of the Corpuscles replace the Fibrin and Albumen of the Liquor Sanguinis, but the proportion of Fat in the former is considerably greater than in the latter; and that although the whole amount of mineral matter (excluding the iron of the Hæmatin, which will amount to 1·17,) is nearly the same in the Corpuscles as in the Liquor Sanguinis, yet that there is a most remarkable and significant difference in its constituents in the two cases respectively. For while the Chlorine of the corpuscles is to that of the liq. sang. as 1 : 2·16, the Phosphoric acid of the corpuscles to that of the liq. sang. as nearly 6 : 1; and whilst the Sodium of the corpuscles is to that of the liq. sang. as 1 : 3·3, the Potassium of the corpuscles is to that of the liq. sang. as 10·3 to 1. Hence it is obvious that the Chloride of Sodium of the blood must be principally contained within the liquor sanguinis, whilst the Potash of the blood is almost wholly included in the substance of the corpuscles; and from the excess of Phosphorus in the corpuscles, as well as of Fat, it may be fairly concluded, that it is in them that the peculiar 'phosphorized fats' are chiefly formed. These facts seem to suggest a very important office for the Red Corpuscles, which is in harmony with all we know of the ratio which their amount in different animals and in different individuals of the Human species, bears to the development of nervo-muscular power (§ 194); namely, that they are especially concerned in preparing the *pabulum* for the Nervous and Muscular tissues, the former of which is distinguished by the presence of phosphorized fats (§ 44), and the latter by the remarkable predominance of the potash-salts (§ 85). And this view derives further confirmation from the fact, that a flesh-diet seems to have a decided effect in promoting the formation of the red corpuscles (§ 161).* The Red Corpuscles appear

* So long as the error of identifying the substance of Muscle with the Fibrin of the Blood prevailed amongst Chemists and Physiologists, the idea stated above would have had little weight; but now that we know that no special relation between them exists (§ 25), we are

o have a remarkable power of absorbing certain gases; for it has been ound by Van Maack and Scherer that a solution of hæmatin possesses a onsiderable power of attracting oxygen, the latter of these chemists aving also ascertained that after the absorption of oxygen there is a light development of carbonic acid; whilst it has been proved by the xperiments of Davy, Nasse, Scherer, Magnus, and Lehmann (see Op. it., band II. p. 180), that the capacity of defibrinated blood (*i.e.* of erum + corpuscles) for absorbing oxygen and carbonic acid, is much greater han that of serum alone, being at least twice as much for equal volumes. Hence it seems certain, that the Red Corpuscles must contain a large proportion of the gases of the blood (§ 163).

143. In addition to what has been already stated of the influence of vater, saline and other solutions, and acetic acid, upon the form and condition of the Red Corpuscles, the following facts may be stated with regard o the effects of these and other reagents.—According to Müller,* the nvelopes of the corpuscles which have been caused to burst by the action f *water*, remain unchanged in the liquid for twenty-four hours or more; but after remaining for some days in contact with it, they are dissolved by it. The nuclei of the nucleated corpuscles, however, resist its solvent action; and these behave, when treated with acids and alkalies, as fibrin or coagulated albumen would do. The action of *acetic acid* upon the wall of the corpuscle is not that of solution, for the membrane is still distinguishable as a delicate film around the nucleus, and may be brought into more obvious view by tincture of iodine; but it seems to occasion the discharge of the coloured contents of the vesicle, either by causing a contraction or collapse of its wall, or (more probably) by augmenting its permeability. The action of the *mineral acids* upon the red corpuscles s quite different; for these occasion a coagulation of the contents of the cells in their interior, so that they are no longer distended by water; and this without producing any other change of shape, than a slight corrugation. *Chlorine* and *alcohol* produce a similar effect. On the other hand, the corpuscles are entirely dissolved by the *mineral alkalies* and by *ammonia;* the cell-walls (and nuclei) disappearing completely, and the cell-contents being diffused through the solution. According to Hünefeld and Simon, the walls of the corpuscles are dissolved, and their contents set free, when they are treated either with *bile* or with *ether;* it is also affirmed by Simon, that *olive oil* exerts a like solvent power; and Hünefeld states that *pure urea* causes the rupture and partial solution of the cell-walls and the dispersion of their contents.† (An admixture of *urine* with the blood seems to exert no other influence upon the corpuscles, than a saline solution of equal density would do, as was long since ascertained by Hewson.)—It is affirmed by Lehmann, however, that the solution of the walls of the blood-corpuscles is rather apparent than real; for that in very few cases is it actually dissolved, being generally transformed into

free to attribute the source of the Muscular structure to whichever component of the Blood seems most likely to afford it; and in the absence of any very positive distinction between the composition and properties of Albumen and Globulin, the peculiar relation between the mineral constituents of Muscle and those of the Red Corpuscles, seem to be the surest guide that we can adopt.

* "Manuel de Physiologie," 4ième edit., traduit par Jourdain, tom. i. p. 92.

† See Simon's "Animal Chemistry," translated by Dr. Day, vol. i. pp. 108–111, and Hünefeld "Der Chemismus in Thierischen Organisation."

a mucous or gelatinous condition, in which it ceases to be distinguishable in consequence of its co-efficient of refraction being the same with that of the plasma. And he founds this conclusion, not merely upon the fact that the capsule is often made visible again, either in its integral state or in fragments, by the addition of tincture of iodine or of some saline solutions; but also upon the viscid and glutinous condition of the blood, after the addition of dilute organic acids, alkaline carbonates, iodide of potassium, and other substances. For these reagents do not reduce either the liquor sanguinis or the serum to a state in which it can be drawn out in threads, and hence this must depend upon the presence of the corpuscles; whilst, moreover, on neutralizing with acids or with alkalies blood which has been thus changed, or on adding to it a solution of iodine or sulphate of soda, the cell-walls of the corpuscles again become visible, and the blood loses its viscidity. It is further remarked by Prof. Lehmann, that some of the Red Corpuscles resist the influence of reagents much more than others do; and he infers that the latter are the older cells, as having the strongest tendency to disintegration; whilst those which present an unusual resisting power, he infers to be young cells which have not yet acquired the normal characters of the red corpuscles.*

144. The Red Corpuscles, when freely floating in the Liquor Sanguinis of blood no longer in motion, exhibit a marked tendency to approximate one another; usually coming into contact by their flattened surfaces, so that a number of them thus aggregated present the appearance of a pile of coins; or, if the stratum be too thin to permit them to lie in this manner, partially overlapping one another, or even adhering by their edges, which then frequently become polygonal instead of circular. The corpuscles when thus adherent, resist the influence of forces which tend to detach them, and will even undergo considerable changes of shape, rather than separate from each other: if forced asunder, however, they resume their normal form. After thus remaining adherent for a time, they seem to lose their attractive force; for they are then seen to separate from each other spontaneously. This peculiar tendency to aggregation is doubtless one of the circumstances which influences the coagulation of the blood; it is most strongly manifested in inflammatory blood, and assists in the production of the buffy coat (§ 189); whilst, on the other hand, it seems to be neutralized by the action of most saline substances, since, if these be added to the blood, the corpuscles do not run together.

145. Besides the red corpuscles of the Blood, there are others which possess no colour and might seem to have a function altogether different; these are known as the *White* or *Colourless* corpuscles (Fig. 11, *c*). Their existence has long been recognized in the blood of the lower Vertebrata, where, from being much smaller than the red corpuscles, as well as from differing widely in shape, they could readily be distinguished. But it is only of late (chiefly through the researches of Gulliver,† Addison,‡ and others), that they have been recognized in the blood of Man and other Mammalia; their size being nearly the same with that of the red corpuscles; and the general appearance of the two (owing to the circular form of the latter, and the absence of a proper nucleus;) being less diverse.

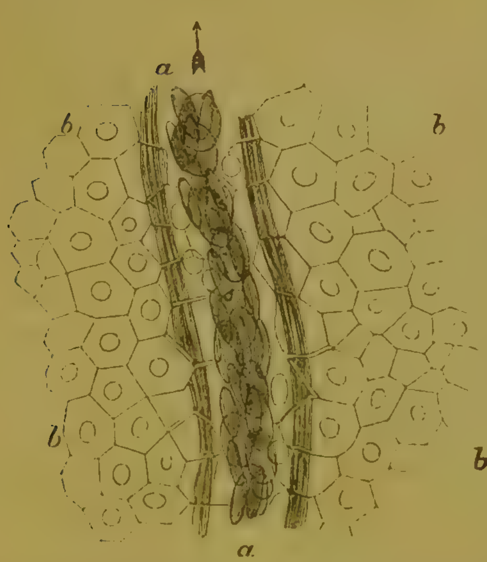
* Op. cit., band ii. p. 175.
† Notes and Appendix to Translation of "Gerber's General Anatomy."
‡ "Transactions of Provincial Medical Association," 1842 and 1843.

t is remarkable that, notwithstanding the great variations in the size of ie *red* corpuscles in the different classes of Vertebrata, the dimensions f the *colourless* corpuscles are extremely constant throughout; their iameter seldom being much greater or less than 1-3000th of an inch in ie warm-blooded Vertebrata, and 1-2500th of an inch in Reptiles. This olds good even in those animals,—the Musk-Deer, and the Proteus,— hich present the widest departure from the general standard in the size f their red corpuscles; so that the colourless corpuscle is as much as ur times the diameter of the red, in one instance; whilst it is not one-ghth of the long diameter of the red, in the other.—The aspect of the olourless corpuscles under the microscope is by no means constant; but ieir variations seem to depend upon their degree of development, and all radations from one condition to another may be readily traced. In their irly state (in which they most resemble the corpuscles of the chyle and mph), the cell-membrane can scarcely be distinguished from the large ucleus to which it is applied, unless the cell be distended with water or cetic acid, which enables us to see that the nucleus is a soft granular iberculated mass, which is disposed to break up readily into two or more agments. In a later stage, however, (of those, at least, which do not go n to be developed into red corpuscles) we find the nucleus apparently ispersed into numerous isolated particles, which give to the entire cell a mewhat granular and tuberculated aspect; and these particles may metimes be seen in molecular movement within the cell. When the olourless corpuscles are treated with a dilute solution of potash, they eedily burst and discharge these granules, whose molecular movement ill continues. The Colourless corpuscles possess, moreover, a higher fracting power than the red; from which they are further distinguished y their greater firmness, and by the absence of any disposition to adhere each other; so that, when a drop of recent blood is placed between two rips of glass, and these are gently moved over one another, the white orpuscles may be at once recognized by their solitariness, in the midst of ie rows and irregular masses formed by the aggregation of the red. This s still better seen in inflammatory blood; in which the Red corpuscles ave a peculiar tendency to adhere to one another, whilst the White are ommonly present in unusual number.

146. The Colourless corpuscles may be readily distinguished in the irculating Blood, in the capillaries of the Frog's foot; and it is then bservable that they occupy the exterior of the current, where the motion f the fluid is slow, whilst the *red* corpuscles move rapidly through the entre of the tube. The Colourless corpuscles, indeed, often show a dis-osition to adhere to the walls of the vessels; which is manifestly increased n the application of an irritant. Hence the idea naturally arises, that to use the words of Mr. Wharton Jones) "there is some reciprocal rela-ion between the colourless corpuscles, and the parts outside the vessels, n the process of nutrition." Of the nature of this relation we have no ertain knowledge; but if the Red corpuscles discharge the function vhich has been suggested for them (§ 142), of preparing the nutrient naterial for Muscle and Nerve, it may not be deemed improbable that he Colourless corpuscles should perform a similar office for the other lbuminous tissues.—A very remarkable spontaneous change of form has een observed by Mr. Wharton Jones to take place in the Colourless

corpuscles whilst being examined under the microscope;* and this not only in the blood of Man, but in that of animals of all the Vertebrated classes, as also in that of Invertebrata, whose only corpuscles are of this character (§ 147). From some point of their circumference a protrusion of the cell-wall takes place, the form of which seems quite indefinite; soon afterwards, another protrusion may be seen to arise from another part of the cell, the first being either drawn in again, or remaining as it was; and thus the configuration of the corpuscles may be seen to undergo several changes before the process finally ceases, and this whilst they are floating in their own serum, and the red corpuscles are lying quite passive in their immediate vicinity. These changes of form, which bear a striking resemblance to those of the Proteus-cell, already referred to (§ 109), are affirmed by Dr. Davaine (by whom they have been more recently studied) to be visible even whilst the blood is circulating through the vessels, in those colourless corpuscles which are retarded by attraction to their walls.†

FIG. 12.




A small Venous trunk, *a*, from the Web of the *Frog's* foot, magnified 350 Diameters; *b*, *b*, cells of pavement-epithelium, containing nuclei. In the space between the current of oval Blood-corpuscles, and the walls of the vessel, the round transparent white corpuscles are seen.

147. The proportion which the White or Colourless corpuscles bear to the Red, is very small in the blood of Man and the higher Vertebrata; being, in the state of health, not more than 1 : 50. It may undergo a great increase in disease, however, as will be shown hereafter (§ 175). In the oviparous Vertebrata, the proportion is higher; thus it has been observed by Wagner ‡ to be as 1 : 16 in the blood of a Frog examined in February, and as 1 : 6 in similar blood examined in August. In one Vertebrated animal, the Amphioxus, the Red corpuscles are wanting altogether, their place in the circulating blood being taken by the Colourless. And in the Invertebrate series generally, the corpuscles of the circulating fluid correspond rather to the *colourless* corpuscles of the Blood of Vertebrata, and to the corpuscles of Lymph and Chyle (which may be regarded as the same bodies in an earlier stage of development), than they do to the *red* corpuscles, which are peculiar to Vertebrata.§ Thus, in one of its most characteristic features, the Blood of Invertebrata (and of Amphioxus) may be likened rather to the Lymph and Chyle of Vertebrated animals, than to their Blood; and this resemblance is strengthened by the fact, that there is no distinction in the former between

* "Philosophical Transactions," 1846, pp. 64, 71, 90, &c.
† "Mémoires de la Societé de Biologie," tom. ii. pp. 103–5.
‡ "Elements of Physiology," translated by Dr. Willis, p. 246.
§ See Mr. Wharton Jones's Memoirs on 'the Blood Corpuscle considered in its different Phases of Development in the Animal Series,' in the "Philos. Trans.," 1846; also "Princ. of Gen. and Comp. Phys.," § 567.

the *absorbent* and the *sanguiferous* vessels, which, in the latter, contain the nutritious fluid in its earlier and its later stages of development. Moreover, the earliest blood-corpuscles of the embryo of even the highest Vertebrata are colourless; and long after the blood has acquired its characteristic hue from the development of red corpuscles, the colourless corpuscles bear a very large proportion to the red, so as even to equal them in number (as the author is informed by Mr. Gulliver) in the blood of fœtal Deer an inch and a half long, and absolutely preponderating in the blood of still smaller embryoes.

148. There can be no doubt that both the Red and the Colourless corpuscles have, like other Cells, a definite term of life; and that, whilst some are undergoing disintegration, others are in a state of advancing development to supply their places, so that the entire mass of both is undergoing continual change. That a new *production* of Red corpuscles may take place with considerable rapidity, we have evidence in the restoration of their normal proportion after it has been lowered by hæmorrhage (§ 162), and in the speedy increase which may be effected in their amount in blood in which they have been excessively diminished by disease (§ 174); this being especially promoted by the administration of Iron, and by a generous diet. On the other hand, various appearances indicative of degeneration may be seen in the Red corpuscles; and this especially in the blood of the Oviparous Vertebrata, which usually contains corpuscles almost destitute of colour, and of shrunken or eroded aspect, their nuclei, however, presenting a remarkable distinctness. The question now arises, in what manner the two classes of Corpuscles are respectively developed, and whether they have any relationship to each other.

149. That the fully-developed Red corpuscles, when ceasing to exist as such, do *not* give origin to new corpuscles of the same kind, may now be asserted (notwithstanding the statements of former observers) to be the concurrent opinion of nearly all who have in recent times specially devoted themselves to this inquiry; for although they may occasionally be seen to undergo duplicative subdivision (§ 104), yet this multiplication only takes place at an early period of their development. The *first* Red corpuscles unquestionably have their origin, like the original cells of the solid tissues, in the primordial cells of the germinal structure; and it is in the so-called 'vascular layer' of the 'blastodermic vesicle' (CHAP. XIX.), and in the mass of cells which constitutes the rudiment of the heart, that this metamorphosis seems first to take place. The situation of the heart, and the course of the principal trunks of the 'vascular area,' are early marked out by the peculiar disposition of the aggregations of cells from which these organs are to be developed; and whilst the *outer* portions of these aggregations are transformed into the *walls* of the respective cavities, the *inner* portions seem partly to deliquesce, and partly to remain as isolated cells floating in the liquid thus produced. These isolated cells are the first blood-corpuscles; and the following account of them is given by Mr. Paget,* who has made them the subject of careful study. "As described by Vogt, Kölliker, and Cramer, they are large colourless vesicular sphe-

* This account is cited from Messrs. Kirkes and Paget's "Hand-Book of Physiology," (pp. 65–8), in which it appears as an abstract of a part of Mr. Paget's Lectures on the 'Life of the Blood,' delivered at the College of Surgeons in 1848.

rical cells, full of yellowish particles of a substance like fatty matter; many of which particles are quadrangular and flattened, and have been called stearine-plates, though they are not proved to consist of that or any other unmixed fatty substance. Among these particles each cell has a central nucleus, which, however, is at first much obscured by them. The development of these embryo-cells into the complete form of the corpuscles is effected by the gradual clearing-up, as if by division and liquefaction, of the contained particles, the acquirement of blood-colour and of the elliptical form, the flattening of the cell, and the more prominent appearance of the nucleus." The process appears to be essentially the same in the Fish, the Reptile, and the Bird; but it takes place too rapidly in the latter class for its stages to be clearly distinguished; whilst in the tadpole the changes occur so slowly that they can be traced in the blood even while it circulates.—The history of the development of the first red corpuscles in Mammalia is nearly the same; but a binary multiplication of these bodies by subdivision has been observed in them, which has not been noticed elsewhere. In watching the stages of this process, it is seen that the partition of the nucleus takes place completely, before that of the cell itself has commenced. — The blood-corpuscles of the Human embryo thus formed, are described by Mr. Paget as "circular, thickly disc-shaped, full-coloured, and, on an average, about 1-2500th of an inch in diameter; their nuclei, which are about 1-5000th of an inch in diameter, are central, circular, very little prominent on the surfaces of the cell, and apparently slightly granular or tuberculated. In a few instances, cells are found with two nuclei; and such cells are usually large and elliptical, with one of the nuclei near each end of the long axis." This first brood of red corpuscles soon disappears, when the lymph and chyle begin to be poured into the blood, being superseded by those developed from the corpuscles brought in by them; and this epoch generally corresponds closely with the alteration in the embryonic circulation, which consists in the obliteration of the branchial arches (CHAP. XIX.). In the Human embryo, the first set of corpuscles seems to disappear entirely by the end of the second month, except in cases of arrested development.

150. The doctrine that the *continued* generation of Red corpuscles is due to the metamorphosis of the Chyle- and Lymph-corpuscles, the Colourless corpuscles of the Blood constituting an intermediate stage of development, is one which has come of late to be very generally received amongst Physiologists; it may be found, however, to require some modification. It rests upon facts of three different orders:—1st, the presence, in all ordinary Blood, of corpuscles exhibiting what appear to be intermediate gradations of development between the Lymph-corpuscle and the true Red corpuscle; and this especially in blood in which an unusually rapid development of red corpuscles is taking place, to make up for previous loss; 2nd, frequent ruddiness in the hue of the fluid of the Thoracic duct, which seems to depend upon the incipient development of Hæmatine in some of its floating corpuscles; and 3rd, the progressive transition from one form to the other, which may be observed in the ascending scale of animal existence. To these considerations may be added, the absence of any other mode of production that can be suggested; since the idea of the self-multiplication of the Red corpuscles is

almost certainly erroneous, and no special organ can be assigned as the seat of their generation.*—The transition-stages between the White and the Red corpuscle are thus described by Mr. Paget† as they are seen in Human blood. "The white corpuscle, at first tuberculated, containing many granules, and darkly shaded, becomes smoother, paler, less granular, and more dimly shaded or nebulous. In these stages the cell-wall may be easily raised from its contents by the contact and penetration of acetic acid, or by the longer action of water; and, according to the stage of development, so are the various appearances which the contents of the cell thus acted-on present. In the regular progress of development, it becomes at length impossible to raise the cell-wall from its contents. Then the corpuscles acquire a pale tinge of blood-colour; and this always coincides with the softening of the shadows which before made them look nebulous, and with the final vanishing of all the granules, with the exception sometimes of one, which remains some time longer like a shining particle in the corpuscle, and has probably been often mistaken for a nucleus. The blood-colour now deepens, and at the same rate the corpuscles become smooth and uniform; biconcave, having previously changed the nearly spherical form for a lenticular or flattened one; smaller, apparently by condensation of their substance, for at the same time they become less amenable to the influence of water; more liable to corrugation and to collect in clusters; and heavier, so that the smallest and fullest-coloured corpuscles always lie deepest in the field. Thus the most developed state of the Mammalian red corpuscles appears to be that in which they are full-coloured, circular, biconcave, small, uniform, and heavy; this is also the state in which they appear to live the longer and most active portion of their lives."—Thus, then, the lymph and chyle seem to be continually supplying, not merely the *pabulum* for organization derived from the food, but an important kind of organized bodies, the existence of which in the blood is essential to the well-being of the entire system; and this view is confirmed by the fact, that the fluid, not only of the thoracic duct, but also of the larger lymphatics, frequently possesses a roseate hue (which sometimes makes itself apparent in the horse even through the walls of the thoracic duct), and that this is attributable to the presence in it of corpuscles which seem to be in process of transformation into the Red corpuscles of the blood, being smaller, paler, and less perfect in shape.‡ — Lastly, the correspondence pointed out by Mr. Wharton Jones (loc. cit.), between the successive phases presented by the Blood-corpuscles in the animal series, and those through which,

* According to the observations of Weber ("Henle and Pfeufer's Zeitschrift," 1846, and "Canstatt's Jahresbericht," 1848), the Liver of oviparous animals appears to assist in the production of Red corpuscles, from the materials furnished by the yolk, during the latter part of intra-oval life, in the Frog and in the Chick. In the Mammal, however, the contents of the yolk-bag (or umbilical vesicle) are exhausted at a very early period of embryonic life, when as yet the liver is rudimentary; so that if this organ takes any share in the development of red corpuscles, it can only perform such a function for a very brief time. At no subsequent period is there any evidence that the Liver is concerned in the development of Red corpuscles; and although the Spleen has been supposed to act as their matrix, yet all the evidence at present in our possession shows that neither to this nor to any other of the "vascular glands" can such a function be justly assigned (§ 172).

† "Hand-Book of Physiology," pp. 69, 70.

‡ See Mr. Gulliver's observations, in his edition of "Hewson's Works," p. 276, and in the Translation of "Gerber's General Anatomy," p. 93.

according to the views above stated, the Red corpuscle passes in attaining its complete form in the highest animal, is really extremely close. For in the blood of the Invertebrata, as in the chyle and lymph, and occasionally in the blood, of Vertebrata, are found 'coarse granule-cells,' which seem to be in the first stage of development, and 'fine granule-cells,' which may be regarded as in the second. This leads on to the 'colourless nucleated cell,' which is the highest form presented by the corpuscles in Invertebrated animals, but is, as we have seen, a mere transitional stage of brief duration in those of Vertebrata. The 'coloured nucleated cell,' again, is the highest form of red corpuscle in the Oviparous Vertebrata; and this corresponds with a more advanced stage of development in the red corpuscle of Mammalia. The 'coloured non-nucleated cells' of the latter are to be regarded as exhibiting that highest phase of development, in which the nucleus disappears, apparently in virtue of the completion of its formative office, and of its resolution into the fluid contents of the cell.

151. Notwithstanding the strength of the foregoing evidence, yet there are certain considerations which render it difficult to give an unreserved adhesion to this doctrine of the transformation of the chyle- and lymph-corpuscles into the red corpuscles of the blood, through the intermediate grade of the white. For although the correspondence in size between the lymph-globule, the colourless blood-corpuscle, and the red corpuscle, is so close in Man as to sanction this idea of their relationship, yet no such correspondence exists elsewhere; for we find that, as the diameter of the lymph-globules and of the *white* blood-corpuscles remains pretty constant, whilst that of the *red* presents a wide range of variation in different animals, there comes to be a strongly-marked disproportion between them; the lymph-globules of the Musk-deer, for example, being of the usual size, whilst the diameter of the red corpuscle is less than 1-12,000th of an inch, or no more than a quarter of the preceding; the lymph-globules of oviparous Vertebrata being usually of no larger diameter than the nuclei of their red corpuscles, and where (as in the Perennibranchiate Batrachia) the red corpuscles are of enormous size, having even a far less diameter than their nuclei. The form of the lymph-globules and of the colourless corpuscles, moreover, is always circular; yet that of the red corpuscles and of their nuclei is oval in all the oviparous Vertebrata, the ratio between the long and the short diameters of the corpuscles being frequently as 2 : 1, and between the diameters of the nuclei being sometimes as 3·3 : 1. Hence until it shall have been shown how these differences are obliterated in the course of the developmental process,—how the lymph-globule of the Musk-deer either contracts or subdivides, so as to form a blood-corpuscle of one-sixteenth of its area,—and how the round lymph-globule of the Proteus swells out into an oval cell of thirty or forty times its dimensions,—the proof must be considered as far from complete. And even if it be admitted that the red corpuscle is originally developed from the lymph-globule, and that this is also the source of the colourless corpuscle, still it would seem quite possible, that the Red and the Colourless corpuscles are to be regarded as two distinct and complete forms, neither being capable of metamorphosis into the other, and each having a specific purpose to serve in the economy. For, so far as can be judged by appearances, there is

a close correspondence between the Colourless corpuscles and the corpuscles of those "Vascular Glands" which are developed in connection with the Absorbent and Sanguiferous systems, and which seem to have it for their office to assist in elaborating the nutrient materials of the blood (CHAP. VIII. SECT. 3). And there are many indications, as will hereafter appear, that their function is not dissimilar; whilst, on the other hand, there is no correspondence between the Red and the Colourless corpuscles, either as to their proportionate development or as to their relations to the system generally in health and disease (§§ 174, 175).—It may be surmised, then, that if the principal part of the lymph-globules really go on to be developed into Red corpuscles, a part may undergo a different course of evolution and become Colourless corpuscles of the blood; and that, having once acquired the latter condition, they do not pass beyond it, but continue to present it during their remaining term of life. Such a diverse mode of evolution from germs that appear to be similar, cannot be thought in itself improbable, when it is borne in mind that all the tissues have their origin, directly or indirectly, in the cells of the embryonic mass, among which not the slightest difference can be observed; and that, whatever is to be the ultimate destination of cells at any period of life, their early aspect is for the most part extremely uniform.

152. *Composition of the Blood.*—The principal components of the Blood having been thus separately described, we have now to inquire into the mode in which they are associated in the liquid as a whole, and the proportions in which they severally present themselves. These are subject, even within the limits of health, to considerable variations; some of which seem to depend upon the constitution of the individual, his diet, mode of life, &c.; whilst others are probably referable to the period at which the last meal was taken, and the amount of bodily exertion made within a short time previous to the analysis. When the results obtained by different experimenters, moreover, are brought into comparison, a very marked discrepancy is frequently found amongst them, especially in regard to the relative proportions of albumen and corpuscles; and this arises in great degree from *the difference of the methods of analysis employed*, as has been recently proved by M. Gorup-Besanez.* For he found that when four samples of *the same* blood were examined by the methods adopted by four different experimenters respectively, the results were as follows.

The first specimen was the blood of a vigorous man fifty years old:

| | Scherer. | Becquerel and Rodier. | Höfle. | Gorup-Besanez. |
|---|---|---|---|---|
| Water . . . | 796·93 | 796·93 | 796·93 | 796·93 |
| Solid matters . . | 203·07 | 203·07 | 203·07 | 203·07 |
| Fibrin . . . | 1·95 | 1·95 | 1·95 | 1·95 |
| Corpuscles . . . | 115·16 | 117·82 | 103·23 | 103·23 |
| Albumen . . | 58·82 | 63·87 | 50·84 | 70·75 |
| Extractive matters and salts | 27·14 | 19·43 | 47·05 | 27·14 |

* "Journ. für prakt. Chem.," band l. p. 346.

The second specimen was from a robust man twenty years old:

| | Scherer. | Becquerel and Rodier. | Höfle. | Gorup-Besanez. |
|---|---|---|---|---|
| Water . . . | 783·63 | 783·63 | 783·63 | 783·63 |
| Solid matters . . | 216·37 | 216·37 | 216·37 | 216·37 |
| Fibrin . . . | 1·56 | 1·56 | 1·56 | 1·56 |
| Corpuscles . . . | 113·54 | 131·52 | 115·12 | 115·12 |
| Albumen . . | 64·32 | 65·91 | 51·76 | 62·74 |
| Extractive matters and salts | 36·95 | 17·38 | 47·93 | 36·95 |

Hence it is of no value whatever to bring together analyses made by different methods, since no reliance can be placed on the results of their comparison; and in estimating the alterations which present themselves in morbid conditions of the blood, it is of course of fundamental importance, that we should take as our standard an average of analyses of healthy blood made by *the same* method. As the greater number of results hereafter to be cited have been obtained by the method of MM. Audral and Gavarret,* which has been followed, with slight modifications, by MM. Becquerel and Rodier,† it will be advantageous here to describe it.—The blood which is being drawn for analysis is received into two different vessels, the first and the last quarters of the whole amount into one, and the second and third quarters into the other; in this manner the similarity of the two quantities is secured as far as possible. The blood in one vessel (A) is allowed to coagulate spontaneously; that contained in the other (B) is beaten with a small rod in order to separate the fibrin. When the coagulation has fully taken place in A, the serum is carefully separated from the crassamentum; and these are then dried and weighed,—1. The Fibrin obtained by the rod (B);—2. The entire Crassamentum (A);—3. The Serum (A). The weight of the separated fibrin gives the amount of it contained in the clot. The weight of the dried residue of the serum gives the proportion of its solid matter to its water. The quantity of water driven off from the clot in drying gives the amount of serum it contained; from which may be estimated the quantity of the solids of the serum contained in the crassamentum. Hence by deducting from the weight of the whole dried clot, first the weight of the fibrin separated by stirring, and then that of the solid matter of the serum as obtained by calculation, we obtain as a residue the weight of the corpuscles. In order to ascertain the whole amount of solid matter in the serum, that which was ascertained by calculation to exist in the coagulum, must be added to that which was obtained from the separated serum. Finally, the proportion of organic and of inorganic matter in the solids of the serum is ascertained by incinerating them in a crucible; by which the whole of the former will be driven off, the latter being left.

153. A modification of this method, which involves somewhat more trouble in its application, but which is more accurate, has been recently proposed by Scherer.‡ The blood is received, as before, into two separate vessels; and in both of these, which are covered to prevent evapora-

* "Essai d'Hæmatologie Pathologique."

† "Recherches sur la Composition du Sang-dans l'état de Santé, et dans l'état de Maladie."

‡ "Canstatt's Jahresbericht," 1848, p. 64; and Haeser's Archiv. band x. p. 191.

tion, coagulation is allowed to take place. Out of the one (A) is to be determined the composition of the serum, and from the other (B) that of the remaining constituents.—Two weighed portions of the serum are taken from the first vessel (A), and one of them is evaporated until all the water is driven off; the residue then represents the entire solid matter of the serum. This, having been weighed, is incinerated; and the residue then left is the saline matter of the serum. The other portion of the serum is poured into boiling water, and stirred with a glass rod, acetic acid being added, drop by drop, as long as any precipitation continues. The albuminous coagulum is then separated by filtration, dried and weighed; and the filtered fluid, after being again examined for any albumen that may be left uncoagulated, is evaporated to dryness. The residue, consisting of the extractive with the salts, is incinerated after having been weighed; and the weight of the salts being thus determined, the difference is that of the extractive matters.—The blood in the second vessel (B), after having been weighed, is put upon a fine linen cloth, and carefully squeezed between the fingers until all the fluid is expressed that can be thus separated, and only the solid coagulum remains behind; this is well washed with distilled water, to get rid of the corpuscles, and the fibrinous residue is dried and weighed. Of the expressed fluid (serum + corpuscles) two portions are again weighed out, as of the serum alone in the previous analysis; one of these serves to determine the relative proportions of the water, of the solid residue, and of the salts; and the other to determine the coagulable proportion of the Albumen and Corpuscles, the coagulation being induced as before, and the filtered residue again serving for the determination of the extractive and soluble salts. — The fatty matters may be determined by boiling in ether, for a sufficient length of time, portions of the fibrin, of the albumen, and of the coagulum of the whole blood, separately. — In summing up the result, the amount of the various solid matters is calculated for 1000 parts of Blood; the remainder is then the watery part of the blood. From the proportion of albumen to water in the serum, the amount of albumen in the whole mass of the blood can be calculated by *its* quantity of water; and the amount of albumen and corpuscles taken together having been determined, that which remains after the deduction of the albumen represents the corpuscles.*

154. Both of the foregoing methods are open to the objection, that the albuminous and other constituents of the Serum are reckoned in the calculation as being equally present in the *whole* water of the blood. Now as the *moist* Corpuscles, according to Lehmann, constitute *fully half* the mass of the blood, and as they do *not* contain the albuminous elements of the serum, and have salines peculiar to themselves, it is obvious that the constituents of the Serum will be estimated far *too high*, and the residue, which expresses the solid matter of the Corpuscles, as much *too low*. In order to avoid this source of error, by separating the corpuscles

* It is a curious indication of the uncertainty of the results of analyses conducted upon principles essentially the same, that whilst, in the *first* of the cases above cited (§ 152), the proportion of corpuscles given by Becquerel and Rodier's method was almost identical with that given by the method of Scherer, there was a marked difference in the proportions of albumen and extractive; whilst in the *second*, the proportion of albumen being almost identical in the two analyses, the amounts assigned to the corpuscles and to the extractive respectively differed by no less than 18 parts in the 1000, for each of these constituents.

from the serum, so as to be able to form a direct estimate of their amount, it has been proposed by M. Figuier to filter the defibrinated blood after having added to it a solution of sulphate of soda, the effect of which is to separate the corpuscles from the serum without causing them to discharge their contents. This method has been adopted by Dumas, Höfle, and Gorup-Besanez, and was employed in the third and fourth of the analyses already cited (§ 152); it would appear from these, however, to produce a still further reduction in the proportion assigned to the corpuscles; and for this it is not difficult to account, when it is borne in mind that the saline solution will tend to empty them of their contents, unless its specific gravity be accurately adjusted (§ 139). Again, it must be borne in mind that the preceding methods of analysis give no account whatever of the Salts contained in the Corpuscles, which, as we have seen, are very different from those of the Serum; and these can only be determined by the incineration of the whole mass of the blood.—Other methods which have been proposed for the more precise quantitative determination of the principal constituents of the Blood, are not only tedious and complex, but involve the use of various reagents, which may themselves induce considerable changes in the 'behaviour' of its organic components;* and in the present state of our knowledge, therefore, it is impossible to arrive at any other than an approximative estimate of their respective amounts. The following is founded on the comparative analyses of the Serum and Liquor Sanguinis already cited from Prof. Lehmann (§ 142); it being assumed that the *moist* Corpuscles form *half* of the entire volume of the blood. This, in his opinion, is rather beneath than above the actual average, which he considers to be 512 parts in 1000; the limits of variation in health being about 40 parts on either side. By halving the numbers in the preceding table, therefore, and adding together those which refer to constituents of the same character, we obtain the following results;—

| | | | | |
|---|---|---|---|---|
| Water | 795·45 | | | |
| Solid residue | 204·55 | | | |
| | | Fibrin | 2·025 | |
| | | Corpuscles: Hæmatin | 8·375 | |
| | | Corpuscles: Globulin and cell-membrane | 141·110 | |
| | | Albumen | 39·420 | |
| | | Fatty matters | 2·015 | |
| | | Extractive matters | 3·270 | |
| | | Mineral substances, exclusive of iron | 8·335 | |
| | | | Chlorine | 2·665 |
| | | | Sulphuric acid | ·090 |
| | | | Phosphoric acid | ·663 |
| | | | Potassium | 1·825 |
| | | | Sodium | 2·197 |
| | | | Oxygen | ·535 |
| | | | Phosphate of Lime | ·212 |
| | | | Phosphate of Magnesia | ·148 |

155. Under the general head of *Fatty Matters* are included several different kinds of fat, some of which present very definite characters, whilst the nature of others has not yet been precisely determined. A

* For an account of the methods of Berzelius, Denis, and Simon, see the "Animal Chemistry" of the last-named author (translated by Dr. Day), vol. i. pp. 167 et seq.

onsiderable part of the whole amount is formed by the *saponifiable* fats, vhich, in the human subject, are Margarin and Olein (§ 37); and it nust be in these that the chief increase occurs, when the amount of atty matter in the blood is temporarily augmented by the entrance of leaginous chyle (§ 161). The proportion of *phosphorized* fat (§ 44), vhich seems to form an essential constituent of the Corpuscles (§ 142), vill probably vary in part with their amount; but the range of variation eems to be too wide to admit of the difference being fully accounted or in this manner. The presence of *Cholesterin* (§ 43) seems to be constant; but it, too, exhibits a considerable diversity in its amount, probably depending upon the relations between the biliary secretion and the espiratory process. Of the fatty substance termed *Serolin* (§ 43), the uantity is always very minute, and it is sometimes inappreciable.—The ollowing table represents the mean, maximum, and minimum amounts f these fatty substances in the healthy blood of the male (the proportion n that of the female being almost precisely similar), according to the nalyses of MM. Becquerel and Rodier.

| | Mean. | Max. | Min. |
|---|---|---|---|
| Saponified fat | 1·004 | 2·000 | ·700 |
| Phosphorized fat | ·488 | 1·000 | ·270 |
| Cholesterin | ·088 | ·175 | ·030 |
| Serolin | ·020 | ·080 | inappreciable. |

The source of the peculiar *odour* of the blood, is probably a volatile atty acid, too minute in its amount to admit of being separately estinated. This odour may be made much more apparent by treating he blood with sulphuric acid, even after it has been long dried; and in ll those animals which are readily distinguishable by their odorous manations, it may thus be made so perceptible as to admit of their lood being distinguished (at least by an individual possessed of a lelicate sense of smell) through its scent alone. Of this test, use has een made with great advantage in juridical investigations.*

156. Under the vague term *Extractive* (§ 64), it is probable that nany different substances are to be ranked; most of them, however, eing either histogenetic substances which are undergoing progressive netamorphosis, such as the peculiar soluble compounds which are considered by Mulder as the binoxide and tritoxide of protein (§ 30); or nonzotized alimentary matters, or products of the retrograde metamorphoses of the tissues, which are on their way to the excretory organs, as s the case with the sugar, urea, uric hippuric acids, creatine and creatinine,† which have been detected in it in minute proportion. It can carcely be doubted that the more attentive study of this part of the lood, will be attended with the discovery of many facts that would throw reat light upon the Chemistry of the histogenetic operations, and of the etrograde metamorphoses of the effete materials of the tissues.

157. The list of the *Inorganic Constituents* of the Blood, which is given in the preceding table (§ 154), does not express the mode in which hey are grouped together; and it takes no account of the Carbonic

* See M. Barreul's researches on this subject in "Ann. d'Hygiène," &c. tom. i. ii. x.

† The discovery of the presence of these two substances in the blood of oxen, has recently een made by MM. Verdeil and Dolfuss, who have operated upon very large quantities of he fluid. (See M. Bérard's "Cours de Physiologie," tom. iii. p. 95.)

acid, which certainly exists in the blood united with Alkaline bases (§ 83). The proportion which the Carbonates bear to the Phosphates, however, seems to be small in Human blood; as is shown by the following table, founded on the analysis of Verdeil,* of the per-centage composition of the ash of the blood, after deducting the carbon still contained in it. The corresponding analyses of the blood of the Dog, Ox, Sheep, and Pig, are here given, to show the remarkable variation between the relative amounts of the Carbonates and Phosphates, in the blood of Herbivorous and Carnivorous animals, of which mention has already been made (§ 84). It will be observed that the proportion of Chloride of Sodium exhibits a remarkable constancy.

| | Man | | Dog | | Ox | | Sheep | | Pig | |
|---|---|---|---|---|---|---|---|---|---|---|
| | A† | B‡ | A§ | B‖ | | | | | | |
| Chloride of Sodium | 61·99 | 55·63 | 49·85 | 50·98 | 59·12 | 53·71 | 57·11 | 50·62 | 41·31 | 49·51 |
| Soda .......... | 2·03 | 6·27 | 5·78 | 2·02 | 13·00 | 14·40 | 13·33 | 13·40 | 7·62 | 5·33 |
| Potassa ........ | 12·70 | 11·24 | 15·16 | 19·16 | 5·60 | 8·76 | 5·29 | 7·93 | 22·21 | 18·54 |
| Magnesia ...... | 0·99 | 1·26 | 0·67 | 4·38 | 0·47 | 0·59 | 0·30 | 0·82 | 1·21 | 0·97 |
| Sulphuric acid .. | 1·70 | 1·64 | 1·71 | 1·08 | 1·25 | 1·16 | 1·65 | 1·91 | 1·74 | 1·34 |
| Phosphoric acid .. | 7·48 | 9·74 | 12·74 | 9·34 | 3·40 | 3·02 | 3·83 | 3·41 | 10·61 | 11·48 |
| Phosphate of lime | 3·55 | 3·21 | 1·32 | 3·05 | 2·51 | 2·32 | 2·38 | 2·68 | 2·88 | 3·17 |
| Peroxide of iron .. | 8·06 | 8·68 | 12·75 | 8·65 | 9·00 | 8·80 | 8·70 | 9·17 | 9·10 | 9·52 |
| Carbonic acid .... | 1·43 | 0·95 | 0·53 | 0·37 | 6·57 | 6·49 | 7·09 | 6·35 | 0·69 | 0·36 |

158. We have now to inquire into the principal modifications, which the relative proportions of these constituents undergo in the state of health, under the influence of varying conditions of the system; and notwithstanding the want of *absolute* correctness in the analyses of which we are at present in possession, those that are made by similar methods give results sufficiently trustworthy to enable them to be compared together, and thus to give a tolerably correct indication of the circumstances which determine the *increase* or *diminution* in the principal components of the Blood.—The first of these modifying conditions which requires special notice is *Age*. During the latter part of fœtal life, the blood is remarkably rich in solid contents; it being in the proportion of corpuscles (including iron) that the chief difference exists between fœtal and maternal blood. This appears from the following comparative analyses made by Denis¶ of the venous blood of the mother, and of the blood of the umbilical artery, which last has been recently found by Poggiale (as might be expected) to be identical with the blood of the fœtus.

| | Venous Blood of Mother. | Blood of Umbilical Artery. |
|---|---|---|
| Water . . | 781·0 | 701·5 |
| Solid constituents . | 219·0 | 298·5 |
| Fibrin . . | 2·4 | 2·2 |
| Corpuscles . . | 139·9 | 222·0 |

* "Ann. der Chem. und Pharm.," band lxix., p. 89.
† Man, forty-five years old, suffering from weak digestion.
‡ Woman, twenty-two years old, sanguineous temperament.
§ After a flesh diet of eighteen days.
‖ After feeding for twenty days upon bread and potatoes.
¶ "Recherches Expérimentales sur le Sang humain," and "Simon's Animal Chemistry," vol. i. p. 238.

| | Venous Blood of Mother. | Blood of Umbilical Artery. |
|---|---|---|
| Albumen . . | 50·0 | 50·0 |
| Phosphorized Fat . | 9·2 | 7·5 |
| Peroxide of Iron . | 0·8 | 2·0 |
| Extractive . . | 4·2 | 2·7 |
| Salts . . | 12·5 | 12·1 |

ıe analyses of Poggiale* give 255·8 parts of solid matter, of which 172·2 .rts were corpuscles, and 2 parts of peroxide of iron, in 1000 parts of :tal blood; thus agreeing with those of Denis in the main fact of the cessive proportion of corpuscles and iron.—The proportion of corpuscles ems to remain high for a short time after birth; but it gradually dimishes; and the whole amount of solid matter in the blood seems to fall its lowest point during the period of childhood. Towards the epoch of ıberty, however, the amount of solid matter increases again, the chief .gmentation being in the corpuscles; and it remains at a high standard .ring the most vigorous period of adult life, after which it begins to cline. This is made apparent in the following table deduced from the alyses of Denis; which are confirmed by those of Lecanu and Simon.†

| | | Solid Constituents. |
|---|---|---|
| In 5 individuals | between 5 months and 10 years . | 170 |
| 13 ,, | ,, 10 years and 20 ,, . . | 200 |
| 11 ,, | ,, 20 ,, 30 ,, . | 240 |
| 12 ,, | ,, 30 ,, 40 ,, . . | 240 |
| 6 ,, | ,, 40 ,, 50 ,, . | 240 |
| 8 ,, | ,, 50 ,, 60 ,, . . | 220 |
| 2 ,, | ,, 60 ,, 70 ,, . | 210 |

159. An appreciable difference exists between the blood of the two :es: that of the male being richer in solid contents, and especially in rpuscles, than that of the female. On this point, the analyses of Lecanu, :nis, and Becquerel and Rodier are in accordance, notwithstanding their ıtual discrepancies; as the following tables show.

| LOOD OF MEN. | *Becquerel and Rodier.* | | | *Denis.* | | | *Lecanu.* | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | Max. | Min. | Mean | Max. | Min. | Mean | Max. | Min. |
| 'ater ........ | 779·0 | 800·0 | 760·0 | 758·0 | 790·0 | 733·3 | 791·9 | 805·2 | 778·6 |
| ɔlid constituents | 221·0 | 240·0 | 200·0 | 242·0 | 266·7 | 210·0 | 208·1 | 221·4 | 194·8 |
| ibrin ........ | 2·2 | 3·5 | 1·5 | 2·5 | 2·9 | 2·1 | | | |
| orpuscles .... | 141·1 | 152·0 | 131·1 | 147·0 | 187·1 | 102·0 | | | |
| lbumen ...... | 69·4 | 73·0 | 62·0 | 57·5 | 63·0 | 52·3 | | | |
| at .......... | 1·6 | 3·2 | 1·0 | | | | | | |
| xtratcive and alts of Serum | 6·8 | 8·0 | 5·0 | | | | | | |
| OOD OF WOMEN. | | | | | | | | | |
| 'ater ........ | 791·1 | 813·0 | 773·0 | 773·0 | 820·0 | 750·0 | 821·7 | 853·1 | 790·3 |
| ɔlid constituents | 208·9 | 227·0 | 187·0 | 227·0 | 250·0 | 180·0 | 178·3 | 146·9 | 209·7 |
| ibrin ........ | 2·2 | 2·5 | 1·8 | 2·7 | 3·0 | 2·5 | | | |
| orpuscles .. . | 127·2 | 137·5 | 113·0 | 138·0 | 162·4 | 88·1 | | | |
| lbumen ...... | 70·5 | 75·5 | 65·0 | 61·2 | 66·4 | 50·0 | | | |
| at .......... | 1·6 | 2·9 | 5·0 | | | | | | |
| xtractive and alts of Serum | 7·4 | 8·5 | 6·2 | | | | | | |

* "Comptes Rendus," tom. xxv. p. 198. † "Animal Chemistry," vol. i. pp. 237–239

From these it would appear that the *mean* excess of the whole solid constituents in the blood of the male above those of the female, is reckoned by the several experimenters at from 12 to 20 parts in 1000; and that the variation is the greatest in the proportion of corpuscles, neither of the other elements exhibiting any considerable difference in their amount in the two sexes. The excess in the solid constituents of the male blood above those of the female is as well marked in the extreme as in the mean results; for the *maxima* in the female do not pass much higher than the *mean* of the male, whilst her *minima* fall far below his; on the other hand, the *maxima* of the male rise far higher than those of the female, whilst his *minima* scarcely descend below her *mean*.

160. It is obvious, from the extent of diversity shown in the preceding table, that the proportions of the constituents must vary considerably with *individual temperament* and *constitution*. All the persons whose blood furnished the subjects of the preceding analyses, were (or considered themselves to be) in perfect health; but their standard of health could not have been by any means uniform. There is no doubt that, in individuals of the plethoric or 'sanguineous' temperament, the proportion of the whole solid constituents, and especially of the corpuscles, is considerably greater than in persons of the 'lymphatic' temperament; and it appears from the analyses of Lecanu,* that the sexual difference in the blood almost disappears when the blood of males and of females of the latter temperament is compared.

161. A considerable influence is exercised on the entire amount, and on the relative proportions, of the constituents of the Blood, by the *previous ingestion of food or drink*, and by the *diet* habitually employed. The observations hitherto made upon the first of these points, however, are not sufficiently numerous to admit of being generalized; and the chief points that can be definitely stated, are those which have been substantiated by Profrs. Buchanan and R. D. Thompson,† in their examination of blood whose serum exhibits the 'milky' appearance, which, when it occurs in health, is due to the entrance of chyle, more rapidly than its oleaginous matter can be eliminated by the respiration or appropriated by the tissues. When a full meal containing oily matter is taken after a long fast, and a small quantity of blood is drawn previously to the meal and at intervals subsequently, the serum, though quite limpid in the blood first drawn, shows an incipient turbidity about half an hour afterwards; this turbidity increases for about six hours subsequently, after which it usually begins to disappear. The period at which the discoloration is the greatest, however, and the length of time during which it continues, vary according to the kind and quality of the food, and the state of the digestive functions. Neither starch nor sugar, nor proteine-compounds, alone or combined, occasion this opacity in the chyle; but it seems essentially dependent upon an admixture of *oleaginous* matter with the food. There are few ordinary meals, however, from which such matter is altogether excluded. When such milky serum is examined with the Microscope, the opacity is found to be due to the presence of an immense number of exceedingly minute granules, resembling in appear-

* "Etudes Chimiques sur le Sang humain," p. 66; and Simon's "Animal Chemistry," vol. i. p. 236.

† "Medical Gazette," Oct. 10, 1845.

ıce those which form the "molecular base" of the chyle. They seem to › composed of two chemically-distinct substances; for when the milky rum is agitated with ether, a part is dissolved, whilst another portion mains suspended; and this latter is soluble in caustic potass. The rmer, therefore, appears to be identical with the "molecular base" of ıe Chyle, and to be of an oily or fatty nature; whilst the latter belongs › the proteine-compounds. The Crassamentum of such blood often exhi-ts a pellucid fibrinous crust, sometimes interspersed with white dots; ıd this seems to consist of an imperfectly-assimilated proteine-compound, ıalogous to that found in the serum. The quantity of this varies accord-g to the amount of the proteine-compounds present in the food.—The resence of *saccharine* matter in the blood (in which it forms part of the xtractive'), after the ingestion of a large quantity of saccharine or fari-ıceous aliment, has been noticed by many experimenters.—It might e fairly presumed that a temporary augmentation must take place in ıe *aqueous* constituent of the blood, whenever any considerable quantity ' liquid is ingested; and yet this augmentation is probably much less onsiderable, under ordinary circumstances, than we should at first be ıclined to suppose. For there exist various provisions in the system he peculiar Malpighian apparatus of the kidneys being the chief) for ıpidly freeing the blood from any superfluity of water; and thus any ccess of fluid absorbed is speedily drawn off again. But further, there is idence that, when the vessels are already filled, absorption does not ıke place with nearly the same readiness as after long abstinence from quids; the rate of absorption being in great degree governed by that at hich the liquid is disposed of. It follows, therefore, that the absorption f even a considerable amount of water within a short time, need not ally involve any great dilution of the blood; and it is probable that a onsiderable previous reduction of its density will only take place in a ate of health, when it has first undergone an unusual elevation, in con-equence of the removal of part of its water by perspiration, diuresis, &c., ithout a corresponding replacement of it by absorption. It has been ffirmed, however, that when Oxen have taken immense draughts of water, ıe blood has been so much diluted, that some of the corpuscles have urst (§ 139) and the colouring matter has passed out of the body; whilst, n the other hand, it has been found that when two dogs had been kept or some weeks on the same kind of food, but one was not allowed to rink, whilst the other was made to take a large quantity of water, the pecific gravity of the blood was nearly the same in each.*—The influence f the *regimen* upon the composition of the blood, however, appears to be ıore definite and constant. An animal diet tends to increase the whole mount of solid matter, but especially to augment the proportion of cor-uscles. On the other hand, a vegetable diet tends to lower the whole mount of solid matter, occasioning a marked reduction in the corpuscles, hilst it seems rather to increase the albumen; thus showing that the lecrease in the corpuscles is not due to a deficiency in their azotized abulum, but depends on some other condition. The development of ibrin appears to take place at least as readily on the vegetable as on the nimal regimen. Hence we see what may, and what may not, be effected

* Dr. Bence Jones in "Medical Times," Aug. 2, 1851, p. 115.

in the treatment of disease, by the adoption of a particular dietetic system, for we may promote or retard the development of the red corpuscles, by the employment of an animal or a vegetable regimen, but can make little or no impression upon the fibrin.*—The effect of complete *abstinence* from food, also, or of a continued insufficient supply of it, is to reduce the proportion of the whole solid constituents; but in this case, too, the corpuscles are much more reduced than the albumen; and very little effect is produced upon the fibrin, which at once undergoes an absolute increase, if any inflammatory affection should develope itself.

162. The effect of *Loss of blood* is of a very similar nature to that of abstinence. Almost as soon as the stream begins to flow from a wounded vessel, there seems to be a transudation of watery fluid from the tissues into the current of blood; for this undergoes a rapid diminution in density, so that the portion last drawn is of lower specific gravity, and contains a considerably smaller amount of solid matter, than that which first issued. This fact, which has long been known, has of late been more precisely determined by Drs. Zimmerman,† Polli,‡ and J. Davy.§ When blood has been repeatedly drawn, or has been lost by hæmorrhage, that which remains is impoverished; but the reduction in its whole amount of solid matter here too lies rather in the diminution of the corpuscles, than in that of the other constituents. This is shown by the following table of the results of MM. Becquerel and Rodier's analyses of the blood of ten patients, each of whom had been bled three times.

| | 1st Venesection. | 2nd Venesection. | 3rd Venesection. |
|---|---|---|---|
| Specific gravity of defibrinated blood | 1056·0 | 1053·0 | 1049·6 |
| " " serum | 1028·8 | 1026·3 | 1025·6 |
| Water | 793·0 | 807·7 | 833·1 |
| Solid Residue | 207·0 | 192·3 | 176·9 |
| Fibrin | 3·5 | 3·8 | 3·4 |
| Corpuscles | 129·2 | 116·3 | 99·2 |
| Albumen | 65·0 | 63·7 | 64·6 |
| Extractive and saline matters | 7·7 | 6·9 | 8·0 |
| Fat | 1·6 | 1·6 | 1·5 |

Hence it is obvious that the special effect of bleeding is to lower the proportion of red corpuscles, and that it has no power of effecting a diminution in the amount of fibrin. We shall find, indeed, that in inflammatory diseases the amount of fibrin undergoes an extraordinary increase (§ 176), which is not checked in the slightest appreciable degree by the most copious venesection.

163. We have now to consider the differences which present themselves in the composition of the blood drawn from different vessels of the same body; these, it is obvious, being dependent on the changes to which the fluid is subjected, during its passage through organs that will appropriate or change its several constituents in an unequal degree. And the first and most important of these sets of differences, is that which exists between *Arterial* and *Venous* blood. The analyses already cited having been made chiefly upon the latter, it will be sufficient here to state the

* See on this subject the treatise of M. Emile Marchand, "De l'Influence comparative du Régime Végétal et du Régime Animal sur le Physique et le Moral de l'Homme."

† "Heller's Archiv." band iv. p. 385.

‡ See "Medico-Chirurgical Review," Oct. 1847.

§ "Anatomical and Physiological Researches," vol. ii. p. 28.

eneral results of comparative inquiries into the composition of the former. he quantity of solid constituents pertaining to the *Corpuscles* is smaller; ey contain relatively more hæmatin and salts, but much less fat. The quor sanguinis is somewhat richer in *Fibrin;* but it contains a larger roportion of water, and consequently less *Albumen.* The *Fatty matters* f the serum, as well as of the corpuscles, are considerably diminished; n the other hand, the *Extractive matters* are decidedly increased. It is ffirmed by Dr. G. O. Rees,* that the phosphorus which exists in venous lood in an unoxidized state, united with the fat of the corpuscles, is conerted by the respiratory process into phosphoric acid, which passes into e serum and unites with alkaline bases; and this view seems borne out y the more recent analyses of Reich.†—The most remarkable difference etween Arterial and Venous blood, however, lies in the amount of *free ases* which they respectively contain. It may now be considered as nquestionably proved by the researches of Stevens, Bischoff, J. Davy, fagnus, and others (but more especially by those of the last-named experienter), that both venous and arterial blood contain Oxygen, Nitrogen, nd Carbonic acid in a state of solution; these gases being yielded up by e blood when it is placed in a perfect vacuum;‡ and carbonic acid being so disengaged when the fluid is shaken with common air or with oxygen, ydrogen, or nitrogen; whilst oxygen is in like manner expelled by ydrogen or nitrogen, which take its place. The experiments of Magnus§ now that from 10 to 12½ per cent of Oxygen (by volume) exists in terial blood; but that this is reduced in venous blood to half its amount. n the other hand, the quantity of Carbonic acid which is thus removable mounts to about 25 per cent (by volume) in venous blood, and to only 0 in arterial. The per-centage of Nitrogen was found to vary from 1·7 3·3; but no constant difference presented itself between the quantities ntained in arterial and in venous blood respectively. The differences the relative proportions of Oxygen and Carbonic acid in arterial and enous blood respectively, confirm the indications afforded by other facts HAP. X.), that an exchange of oxygen for carbonic acid takes place in the stemic circulation, and an exchange of carbonic acid for oxygen in the eneral circulation. How far the gases thus introduced into the blood nter into chemical combination with any of its constituents, or are erely dissolved in the liquid, has not been positively determined; there reason to think, however, that if combination thus takes place, the proortion so employed is extremely small.‖ The remarkable power of bsorbing carbonic acid, which is possessed by the Serum, and still more y the Red Corpuscles, has been already mentioned (§§ 84, 142); and there ould be no difficulty in accounting for the presence of many times the nount of that gas which is actually found in the blood, without supposing it to lose its freedom by combination.

* "Philosophical Magazine," vol. xxxiii. p. 28.

† "Archiv. der Pharmacie," and "Liebig and Kopp's Report," for 1849, p. 366.

‡ It has been found by Magnus, that carbonic acid is not given off under the receiver of air-pump, until the air has been so far exhausted that it only supports one inch of mercury. his fact explains the negative result obtained by many experimenters; since an extremely od air-pump is required to produce such a degree of exhaustion.

§ See "Ann. der Physik und Chemie," band lxvi. p. 177; and an abstract in the "Philophical Magazine," Dec. 1845.

‖ See Lehmann, Op. cit., band ii. p. 181.

164. The increase of the Fibrin, however, which seems to be effected during the aeration of the Blood, must be taken as an indication that a certain part of the oxygen absorbed from the air is made directly subservient to changes in the composition of the circulating fluid; and from what has been already stated (§ 25), it appears that the fibrin of arterial blood is in a state of higher oxidation than that of venous. Now although, for the reasons formerly given (§§ 25–29), we must regard the conversion of albumen into fibrin as rather a *vital* than a *chemical* change, yet the existence of the difference in question obviously points to the presence of oxygen as a condition essential to its performance; and this inference is fully confirmed by the recent experiments of Dr. Gairdner,* on the influence of the respiration of pure oxygen on the production of fibrin. As the Rabbit was on many accounts the most convenient warm-blooded animal for such a trial, he first set himself to determine the normal proportions of the constituents of its blood. The analysis of the blood drawn from the aorta in six healthy individuals yielded the following results.

| | Mean | Max. | Min. |
|---|---|---|---|
| Fibrin . . | 1·65 | 2·00 | 1·45 |
| Corpuscles . | 82·35 | 92·00 | 70·00 |
| Albumen . . | 46·30 | 58·00 | 37·20 |

On the other hand, the analysis of the blood of three individuals which had been made to respire pure oxygen for half an hour, gave the following as the proportions of its components.

| | Mean | Max. | Min. |
|---|---|---|---|
| Fibrin . . | 2·40 | 2·50 | 2·30 |
| Corpuscles . | 69·56 | 75·00 | 60·50 |
| Albumen . . | 40·23 | 45·70 | 35·00 |

It is further stated by Dr. Gairdner (Op. cit., p. 183), that a rabbit having been kept for half an hour under the influence of an electro-magnetic current between the chest and spine, which produced a great acceleration in the respiratory movements, its blood was found to contain as much as 2·9 parts of fibrin in 1000.—The larger quantity of fibrin in arterial blood of itself renders its coagulum firmer; but independently of this, there would seem to be a difference in the quality of the fibrin, which, when separated by stirring or whipping, is more tenacious and compact in arterial than in venous blood.

165. The proportion of Red Corpuscles in arterial and venous blood respectively, has been variously stated by different observers; and we may easily conceive it to be affected by several circumstances, which may produce a change in the whole proportion of the solid to the fluid constituents of the blood, during the course of its circulation. Thus, the discharge of the contents of the thoracic duct into the venous system near the heart, will tend to dilute the blood of the pulmonary and arterial circulation; whilst, conversely, the escape of the watery part of the blood by the renal and cutaneous secretions, and by transudation into the tissues, which takes place during its passage through the systemic capillaries, will tend to augment the proportion of the solids of the blood drawn from the systemic veins. On the other hand, if the discharge of

* Treatise "On Gout," 2nd edit., pp. 153-4.

fluid from the thoracic duct be suspended, and the amount absorbed from the tissues during the systemic circulation should exceed that which is transuded (as appears sometimes to happen, § 162), then the proportion of solid matter will be less in venous than in arterial blood.—No such explanation will apply, however, to the very marked differences exhibited in Dr. Gairdner's experiments just cited, between the proportions of red corpuscles and of albumen in the ordinary arterial blood of rabbits, and in that of the individuals whose blood had been hyper-arterialized; the sum of the averages in the former case being 128·65, and in the latter 109·79, the difference of which is 18·86, or nearly *one-seventh* of the larger amount. Still, that this difference is in great part due, rather to dilution of the blood, than to the absolute diminution in its entire amount of red corpuscles and of albumen, would seem probable from the fact that their *relative* amount is almost exactly the same in the two cases, the proportion of corpuscles to albumen being 1·78 : 1 in the normal blood, and 1·72 : 1 in the oxygenated.*

166. The difference in the hues of arterial and of venous blood, which is entirely dependent upon the state of the Red Corpuscles, has been supposed to be produced by a chemical change exerted upon their Hæmatin (§ 31) by oxygen and carbonic acid respectively. Of such change, however, there is no adequate evidence; and there are many indications that we are to look for the source of the difference of colour, rather in modifications in the *form* of the corpuscles, affecting their power of transmitting and reflecting light, than in any chemical alterations of their *contents*. It is true that if arterial blood be exposed to carbonic acid out of the body, it will acquire the dark hue of venous blood; whilst, conversely, venous blood exposed to oxygen will acquire (on its surface at least) the florid hue of arterial blood. But for these changes to take place, it is necessary that the normal proportion of saline matter should exist in the serum in which the corpuscles float, and that the corpuscles themselves should not have ruptured and discharged their hæmatin. For if arterial blood deprived of its fibrin be diluted with twice or thrice its volume of water, it assumes a dark venous tint, which is not affected by the passage of a current of oxygen through it; yet the red colour is restored by the addition of a saturated solution of a neutral salt, even without the contact of oxygen. On the other hand, venous blood is reddened by the addition of a strong saline solution, without any exposure to oxygen; and it is not readily darkened again by the passage of carbonic acid through it. Again, a scarlet clot is darkened by washing it with distilled water, and is only very slowly reddened by exposure to oxygen; whilst a black clot becomes at once scarlet when it is washed with salt, and is not blackened again by carbonic acid. Further, if the corpuscles be treated with water until they burst, so that the hæmatin is diffused through the liquid, scarcely any effect is produced upon the hue of the solution, either by carbonic acid, by oxygen, or by salines; such slight alteration as does occur being fairly attributable, either to the presence of a few corpuscles still unruptured, or to the influence which the absorption of these gases may produce upon the colouring matter, without entering into chemical combination with

* It would be important to determine the comparative amount of carbonic acid, and of the solids of the urine, excreted in the same time by two sets of animals placed under these very diverse conditions.

it.*—Hence it is obvious that the light or dark colour of the blood affords no indication whatever of its state of oxygenation, since the change from the one to the other may be effected by other agents; and if we examine into the nature of their influence, we find that the blood is *darkened* by whatever tends to *distend* the corpuscles, so as to render them flat or bi-convex, whilst it is *brightened* by whatever tends to *empty* them, so as to render them more deeply bi-concave than usual. And observation of the effects of oxygen and carbonic acid, respectively, upon the form of the corpuscles, confirms the idea that this is the mode in which these agents affect their colour; for the former causes their contraction, and renders their cell-walls thick and granular, so as to increase their power of reflecting light; whilst the latter, producing a dilatation of the corpuscles, thins their cell-walls, and enables them to transmit light more readily. That an increase in the opacity and reflecting power of the corpuscles tends to heighten the colour of the blood, is shown by an experiment of Scherer's; who found that when defibrinated blood had been darkened by the addition of water, its original bright colour was restored by the addition of a little milk, oil, or finely-powdered chalk or gypsum.†

167. No difference can be detected between samples of blood drawn from various parts of the *arterial* system of the same animal; but very important variations exist, as might be expected, in the composition of the blood drawn from the several parts of the *venous* system, since the changes to which it has been subjected in the several organs through which it has passed, are of a very diversified character. The blood of the vena portæ, for example, differs considerably from the blood of the hepatic vein, and both of these differ from the blood of the jugular. So, again, the blood of the splenic vein differs from all the preceding; and so must the blood of the renal vein, although this latter difference has not yet been demonstrated by direct analysis. The most important and best-established of these diversities will now be enumerated.—In speaking of the composition of the blood of the *Vena Portæ*, it must be remembered that this consists of two very distinct factors, namely, the blood of the *gastric* and *mesenteric* veins, and the blood of the *splenic* vein; the former having been altered by the introduction of solid and liquid alimentary matters, and the latter by its circulation through the spleen. These, therefore, ought to be separately studied; and this has been done by M. Jules Béclard.‡ The characters of the blood returning by the Gastric and Mesenteric veins from the walls of the alimentary canal, are of course affected by the stage of the digestive process, and by the nature and amount of the absorbable matters. As compared with the ordinary venous blood, the total quantity of its solid constituents is lowered during the early part of the digestive process, by the dilution it suffers through the imbibition of liquid; and this diminution is especially remarkable in the corpuscles, the relative proportion of albumen being increased

* It has been shown by Peligot, that the colours of solutions of the salts of the protoxide of iron are considerably modified by passing a current of protoxide of nitrogen through them, although no chemical change is thereby induced.

† See, on this subject, the Reports by Scherer in "Canstatt's Jahresbericht" for 1844 and subsequent years, and the works therein referred to; also Mulder's "Chemistry of Animal and Vegetable Physiology" (translated by Prof. Johnston), pp. 338—344.

‡ See his Memoir in the "Arch. Gén. de Méd.," 4e série, tom. xviii., p. 322, et seq.; and his edition of his father's "Elémens d'Anatomie Générale," pp. 265, 266.

by the introduction of new albuminous matter from the food. Towards the conclusion of the digestive process, however, the blood of the mesenteric veins gradually comes to present the ordinary proportions of these two components; and in an animal that has been subjected to long abstinence, it does not differ from that of the venous system in general. The quantity of extractive is usually increased; and in this part of the blood it must be, that sugar, dextrin, gelatin, and other soluble organic matters that are taken into the circulation, are contained. Some of these have in fact been detected in it.* The fibrin of the blood of the mesenteric veins appears to be less perfectly elaborated than that of the blood in general; for the blood of the mesenteric veins coagulates less perfectly (having been erroneously asserted by some not to coagulate at all); and its fibrin, when separated by stirring, shows a marked deficiency in tenacity, and liquifies completely in the course of a few hours. A part of the albuminous constituent of the blood does not present the characters of true albumen, for it is not precipitated by heat or by nitric acid, and the precipitate thrown down by alcohol is redissolved by water; like albumen, however, it is precipitated by the metallic salts, creosote, and tannin. This substance, which has been distinguished by M. Mialhe as *albuminose*, further differs from true albumen in the facility with which it traverses organic membranes; for these resist the passage of albumen, while they are freely transuded by albuminose. And it is affirmed by M. Mialhe, that the want of that conversion of albuminose into albumen, which ought to take place as part of the assimilating process, is one cause of the readiness with which albuminous matter transudes from the blood in albuminuria and in dropsies; this albuminous matter frequently having rather the characters of albuminose, than those of true albumen.†

168. On the other hand, the blood of the Splenic vein exhibits a notable diminution in the proportion of red corpuscles, whilst its albumen is greatly augmented, the total amount of its solid matter differing but little from that of arterial blood; as is shown by the following comparative statement of the proportions of the water and the solids of the blood of the same animal in different parts of its circulation.

| | External Jugular Vein. | Mammary Artery. | Splenic Vein. |
|---|---|---|---|
| Water . . . | 778·9 | 750·6 | 746·3 |
| Albumen . . . | 79·4 | 89·5 | 124·4 |
| Corpuscles and Fibrin | 141·7 | 159·9 | 128·9 |

A part of this augmented albumen exists in the form of neutral albuminate of soda (§ 20); so that the serum of the splenic blood (as shown by Scherer) becomes turbid on the addition of water. The proportion of fibrin seems to be larger in the blood of the splenic vein, than in that of the venous system in general; but, like that of the mesenteric vein, the separated fibrin is deficient in tenacity, and early passes into the state of liquefaction. The serum of the blood of the splenic vein of the horse was found by M. Béclard in two instances to undergo spontaneous coagulation, five and eight hours after its removal from the crassamentum, in

* See the Researches of MM. Bouchardat and Sandras, in the "Supplément à l'Annuaire de Thérapeutique," 1846.

† See the "Cours de Physiologie" of M. Paul Bérard, tom. iii. p. 87.

contact with which it had been left for the preceding twenty-four hours. This spontaneous coagulation indicates the existence of a compound of a fibrinous nature, which, however, could not have been fully elaborated, since it did not coagulate with the true fibrin, and which differed from albumen in the spontaneity of its change of state; and we may consider the substance, with much probability, to have been in a transition-state between the two. The peculiar cells containing red corpuscles, which form part of the parenchyma of the Spleen (CHAP. VIII. SECT. 3), are not unfrequently to be observed in the blood of the splenic vein; being very abundant, according to Ecker, in that of the horse.

169. Many comparative observations have been made upon the blood of the *vena portæ* and of the *hepatic vein;* but a large part of them, according to M. Cl. Bernard, are vitiated by the fact, that, unless the vena portæ be tied, a reflux of blood takes place into it from the liver, so that the blood which flows when it is wounded, is not so much portal as hepatic blood. According to this experimenter, the blood of the hepatic vein is peculiar as containing an increased proportion of sugar and fat, which are generated from its other components during its passage through the liver (§§ 40, 45–47); and he also maintains that there is a decided augmentation in the quantity of fibrin which it contains.* At any rate, the albuminous constituent undergoes some change in passing through the liver, by which it is rendered more fit to enter the general circulation; for it has been found by M. Bernard, that whilst a solution of the albumen of the egg, injected into the jugular vein, speedily occasioned a transudation of albumen into the urine, no such transudation occurred when a similar solution was injected into the vena portæ.†—According to Prof. Lehmann, the blood of the hepatic vein further differs from that of the portal in the following particulars. "It is far poorer in water; so that, assuming the solid constituents of the blood to be equal in both kinds of blood, the quantity of water in the blood of the portal vein is to that in the blood of the hepatic vein as 4 : 3 during digestion and when not much drink has been taken, and sometimes as much as 12 : 5 after digestion has been fully accomplished. The clot of the blood of the hepatic vein is bulky, and readily breaks down; whilst 34 parts of serum are separated from 100 parts of portal blood, only 15 are separated from 100 parts of the blood of the hepatic vein. The blood of the hepatic vein is far richer in blood-cells, both coloured and colourless, than that of the portal vein; the colourless corpuscles occur in the most varied shapes and sizes; the coloured are seen in heaps of a distinct violet colour, and their capsules are less readily destroyed by water than are those of the blood of most other vessels; while in the blood of the portal vein there are 141 parts of moist blood-cells to 100 parts of plasma, in the blood of the hepatic vein there are 317 parts of moist blood-cells to 100 of plasma. The cells in the blood of the hepatic veins are poorer in fat and in salts, and especially in hæmatin, or at least iron, but somewhat richer in extractive matters. Their specific gravity is higher than that of the cells of the portal blood, notwithstanding the diminished quantity of iron. The plasma of the blood of

* "L'Union Médicale," Sept. 23, 1850. M. Bernard does not give any details on this point; and he does not seem to have made allowance for the admixture of the blood of the hepatic artery with that of the portal vein.

† "Gazette Médicale," 1850.

he hepatic veins is far denser than that of the blood of the portal vein, or it contains a much larger amount of solid constituents generally, lthough little or no fibrin is to be found in it (?). While 8·4 parts of olid matter correspond to 100 of water in the serum of portal blood, ere are 11·8 parts of solid matter to an equal quantity of water in the rum of the blood of the hepatic veins. If we compare the solid con-ituents of the serum of both kinds of blood, we find less albumen and t, and far less salts, in the blood of the hepatic veins, while the quantity extractive matter, including sugar, is perceptibly augmented."*—It nnot be doubted that when the secretion of urine is proceeding with pidity, the blood of the *renal vein* must contain a smaller proportion water than that of the renal artery, and that the quantity of salines so must be diminished; since a separation of these ingredients takes ace in the passage of the blood through the renal capillaries. So far as gards the quantity of water, this *a priori* conclusion has been confirmed the analyses of Simon, who found 790 parts of water in 1000 of ood drawn from the renal artery, and only 778 in blood drawn from e renal vein of the same animal.† The proportion of salts, however, s not been analytically determined to be different.

170. *Alterations in the Composition of the Blood in Disease.*—Under is head it is intended here to consider, not the state of the Blood in ery principal type of disease (which it is the duty of the Pathologist investigate), but the most important facts which the study of its orbid conditions has afforded, towards the determination of the con-tions under which decided variations take place in the quantity or ality of its principal components, and of the effects which those varia-ns produce upon the system at large. The first series of such con-cted researches, as afford the requisite materials for this inquiry, was at of MM. Andral and Gavarret,‡ which is still of standard value; is was followed by the investigations of MM. Becquerel and Rodier;§ d many additional analyses have been made by Popp, Simon, and ner observers. For the purpose of comparison, however, as already marked, it is desirable to employ these results only, which have been tained by processes essentially the same; and hence the following mmary will be chiefly based on the statements of the French experi-menters whose researches have been just referred to.—It is necessary, wever, in the first place, to assume some standard of composition, which y be regarded as sufficiently characteristic of health, to lead us to rank y variation which passes beyond its limits as essentially morbid; and s standard must be fixed according to the method of analysis em-yed. Thus, although it has been shown (§ 154) that the calculation the proportionals of the principal constituents of the blood, from the ults obtained according to the method of MM. Andral and Gavarret, ist be held to be in itself erroneous, yet as the same method was followed all the analyses of morbid blood made by them and their successors, requisite standard must be erected upon this foundation; and the fol-ving may thus be considered as the normal range of variation for the

"Lehrbuch der Physiologischen Chemie," band ii. p. 250.

"Animal Chemistry," translated by Dr. Day, vol. i. p. 214.

"Essai d'Hæmatologie Pathologique."

"Recherches sur la Composition du Sang dans l'Etat de Santé et dans l'Etat de Maladie."

principal constituents of the blood in health, according to the foregoing mode of estimating them (§ 152).

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Fibrin . . . | from | 2 | to | $3\frac{1}{2}$ | parts per 1000. | | |
| Red Corpuscles . | „ | 110 | „ | 152 | „ | „ | |
| Solids of Serum . | „ | 72 | „ | 88 | „ | „ | |
| Water . . | „ | 760 | „ | 815 | „ | „ | |

171. The first of these components whose variations we shall consider, is *Fibrin;* the estimate of which, however, is open to an important fallacy, that has not been sufficiently guarded against,—namely, the admixture of the Colourless corpuscles. "These," as Mr. Paget correctly remarks, "cannot, by any mode of analysis yet invented, be separated from the fibrin of mammalian blood; their composition is unknown, but their weight is always included in the estimate of the fibrin. In health, they may, perhaps, add too little to its weight to merit consideration; but in many diseases, especially in inflammatory and other blood-diseases in which the fibrin is said to be increased, these corpuscles become so numerous that a large proportion of the supposed increase of the fibrin must be due to their being weighed with it. On this account, all the statements respecting the increase of fibrin in certain diseases need revision."* Some idea may probably be formed of the relative proportion of fibrin and colourless corpuscles, in the colourless coagulum obtained by stirring the blood or by washing the ordinary clot, or in that which forms the 'buffy coat' (§ 189), by attending to its texture; for where this is unusually firm and almost leathery, as it commonly is in the blood of a person suffering under a 'sthenic' inflammation, either the proportion of fibrin must be augmented, or its plasticity must be increased, or both conditions must coexist; whilst, on the other hand, when the colourless clot, though bulky, is deficient in tenacity and is easily broken down between the fingers, as happens with that of blood drawn from tubercular subjects when no inflammation is present, the increase is probably due rather to an augmentation in the colourless corpuscles, than to that of the fibrin.—In the results of the analyses now to be stated, it must be borne in mind that the term 'fibrin' really designates the 'colourless coagulum' of spontaneous formation, whatever may be its composition.

172. The most important fact substantiated by Andral, is one that had been previously suspected,—the invariable increase in the quantity of Fibrin during acute Inflammatory affections; the increase being strictly proportional to the intensity of the inflammation, and to the degree of symptomatic fever accompanying it. "The augmentation of the quantity of Fibrin is so certain a sign of Inflammation, that, if we find more than 5 parts of fibrin in 1000, in the course of any disease, we may positively affirm that some local inflammation exists." Several cases are mentioned, in which an increase to 7 or $7\frac{1}{2}$ parts took place, without any apparent cause; but in which it afterwards proved that severe local inflammation had been present; and thus we are furnished with a pathognomonic sign of great importance. The average proportion of Fibrin in Inflammation may be estimated at 7; the minimum at 5; the maximum at 13·3. The greatest augmentation is seen in Pneumonia and Acute Rheumatism. It does not appear that in robust athletic persons, the proportion of Fibrin is greater than in those of feeble constitution; in the

* Kirkes and Paget's "Hand-book of Physiology," p. 57.

latter it is the Corpuscles that are deficient; and it is rather from this disproportion, than from an absolute excess of Fibrin, that their greater liability to Inflammatory affections arises. Diseases which commence at the same time as the Inflammation, or which co-exist with it, do not prevent the characteristic increase of the Fibrin; thus in Chlorotic females, the proportion rises to 6 or 7, under this influence. The augmentation is observed at the very outset of the affection; the quantity increases with its progress; and a decrease shows itself when the disease begins to abate.* When the disease presents alternations of increase and decline, these are marked by precisely corresponding changes in the quantity of Fibrin. An augmentation is commonly observable during the advanced stage of Phthisis, in spite of the deterioration which the blood must then have undergone; this is probably dependent upon the development of local inflammation around the tubercular deposits. In one of Popp's observations, the proportion of Fibrin in the blood of a Phthisical patient was not less than 10·7.—Some experiments performed by M. Andral on the blood of pregnant women, seem to lead to the conclusion that, during the first six months, the Fibrin is below the normal standard; and that it subsequently varies, usually undergoing an augmentation between the sixth and seventh, and the eighth and ninth months. There is also a diminution in the Corpuscles; and these circumstances combined favour the production of the 'buffy coat' (§ 190). These observations are confirmed by those of MM. Becquerel and Rodier.

173. It appears obvious, from what has been just stated, that the increase in the quantity of Fibrin is not *dependent upon* the febrile condition, which is secondary to the local inflammation, but upon the Inflammation itself. This conclusion is confirmed by the interesting fact that, in idiopathic Fever, the proportion of Fibrin is diminished, instead of undergoing an increase. This diminution was constantly observed by Andral in the premonitory stage of Continued Fever; in some instances the amount was no more than 1·6 parts in 1000. The proportion of Corpuscles was found to have usually, but not constantly, undergone an increase; as had also that of the solid parts of the Serum. In ordinary Continued Fever, in which there was no evident complication from local disease, the quantity of Fibrin varied from 4·2 to 2·2; that of the Corpuscles from 185·1 to 103·6 (excluding a case in which their amount was only 82·5, which was that of a Chlorotic female); that of the solid matter of the Serum, from 98·7 to 90·9; and that of the Water from 725·6 to 851·9. Hence the quantity of solid matter appears to be usually increased; but the peculiar condition of the blood in this disease may probably be stated to be (so far as regards the proportions of its principal constituents) a diminution of the Fibrin in proportion to the Red Cor-

* By experiments on animals, M. Andral has ascertained that no circumstance of previous debility or privation prevents this characteristic change. Having ascertained the amount of fibrin in the blood of three dogs to be 2·3, 2·2, and 1·6 (the natural range for these animals), he deprived them, completely or partially, of food. On the fourteenth day, the proportion of fibrin had risen, in the first to 4·5, and in the second to 4; these animals had no food. In the third dog, which was supplied with a very small quantity of food daily, the same condition developed itself at a later period; the blood on the fourteenth day exhibiting only 1·8 parts of fibrin; but on the twenty-second day presenting 3·3 parts.—In all these instances, the elevation in the proportion of Fibrin was coincident with Inflammatory changes in the stomach.

puscles. When, however, a local Inflammatory affection developes itself during the course of the Fever, the amount of Fibrin increases; but its augmentation seems to be kept down by the febrile condition.—In Typhoid Fever,* the decrease in the proportion of Fibrin is much more decidedly marked; this does not depend upon abstinence; for it ceases as soon as a favourable change occurs in the disease, long before the effect of food could show itself. In the various cases examined by Andral, the blood furnished a maximum of 3·7 of fibrin, and a minimum of 0·9; in this last case, the typhoid condition existed in extreme intensity, yet the patient recovered. The proportion of Corpuscles varies considerably; in an early stage of the disease it is usually found to be absolutely high; and it always remains high relatively to the amount of fibrin. In Typhoid Fever, then, the abnormal condition of the Blood, in regard to the disproportion between the corpuscles and the fibrin, is more strongly marked than in ordinary continued fever: yet the usual augmentation of fibrin will take place, if a local inflammation developes itself.—In 'putrid' or 'malignant' fevers, there appears to be a very marked diminution, not only in the fibrin, but in the other solid constituents of the blood; and in their advanced stages, the blood may entirely lose its power of coagulation. Thus in a case of 'typhus abdominalis,' in which the blood was analysed by Simon, he found only 112·5 parts of solid matter, of which 54 parts were albumen, the corpuscles only constituting $47\frac{1}{4}$ parts, and the fibrin being altogether deficient. In the Exanthematous Fevers, it does not appear that the proportion between the fibrin and the corpuscles undergoes so striking a change, as in ordinary continued fever; but the number of cases examined has been too small to admit of decided conclusions. It is evident, however, that the specific Inflammations proper to, and characteristic of, these Fevers, have not the same effect in occasioning an increase of the Fibrin, as an intercurrent Inflammation of an extraneous character.—It has been asserted that the proportion of Fibrin is diminished in Scurvy; but this, from the analysis of MM. Becquerel and Rodier, Chatin and Bouvier,† and Mr. Busk,‡ appears not to be the case, the proportion of fibrin being rather above than below the normal average. In Cholera, however, a reduction in the coagulable element of the blood seems to be an almost constant occurrence; and in some instances, the blood, although loaded with solid matter, has scarcely coagulated at all. Of the blood drawn during life, it has been observed that the clot is loose and grumous, often not shrinking and expelling serum; and that this change presents itself in a degree corresponding to the severity and advanced stage of the disease. And when the blood has been removed from the body after death, the clots have been found loose and fragile in texture, sometimes almost semi-fluid.§—It appears from the experiments of Magendie, that one of the effects of a diminution in the proportion of Fibrin, is a tendency to the occurrence of Hæmorrhage or of Congestion, either in the parenchymatous tissue, or on the surface of mem-

* M. Andral confines this term to the species characterised by ulceration of the mucous follicles of the intestinal canal.

† "Journ. de Chimie Médicale," Mars, 1848.

‡ "Library of Medicine," Vol. v. p. 90.

§ See Dr. Parkes's "Researches into the Pathology and Treatment of the Asiatic or Algide Cholera," pp. 32, 73.

ranes: and these conditions are well known to be of frequent occurrence, s complications of many of the above disorders. A marked diminution f Fibrin was noticed also, by M. Andral, in many cases of Cerebral ongestion, which commences with headache, vertigo, and tendency to pistaxis, and not unfrequently passes into coma and apoplexy. In Apolexy, the diminution of Fibrin was still more striking; and in general, iere was found to be an increase of the Corpuscles. In one instance, ie quantity of Fibrin on the second day of the attack was found to have illen to 1·9, whilst that of the Corpuscles had risen to 176·5; but on the iird day, when the patient's consciousness began to return, the quantity f Fibrin was 3·5, whilst that of the Corpuscles had fallen to 137·7. It ould seem from the great change in the character of the Blood, which as noticed in this and in other instances, that the want of due proportion etween the Fibrin and the Corpuscles may have been the cause, rather ian the effect, of the Apoplectic attack. In a case of Purpura Hæmoriagica in which the blood was analysed by Routier,* the proportion of orpuscles was normal (nearly 122 parts in 1000), whilst the fibrin only mounted to 0·9 parts in 1000.

174. The amount of *Red Corpuscles* seems to be subject to greater uriation within the limits of ordinary health, than is that of fibrin. In ie condition which is ordinarily termed a highly sanguineous temperaient, or Plethora, it is chiefly the entire mass of the blood that undergoes a increase; but whatever excess there may be in the proportion of its solid onstituents, this affects the Corpuscles rather than the fibrin. Plethoric ersons are not more prone to Inflammation, than are those of weaker onstitution; but they are liable to Congestion, especially of the brain, nd to Apoplexy or other Hæmorrhage. The effect of Bleeding in dimiishing this tendency is now intelligible; since we know that loss of blood educes the proportion of Corpuscles.—On the other hand, in that tempeiment,† which when exaggerated, becomes Anæmia, there is a marked iminution of the Corpuscles; this temperament may lead to two different onditions of the system. In Chlorosis, the Red Corpuscles are dimiished, whilst the Fibrin remains the same; so that the clot, though nall, is firm, and not unfrequently exhibits the buffy coat; in some xtreme cases of this disease, the Corpuscles have been found as low as 27. he influence of the remedial administration of Iron, in increasing the uantity of Corpuscles, was rendered extremely perceptible by Andral's nalyses; in one instance, after iron had been taken for a short time, the roportion of Corpuscles was found to have risen from 49·7 to 64·3; hilst in another, in which it had been longer continued, it had risen om 46·6 to 95·7. On the other hand, Bleeding reduced still lower the roportion of Corpuscles; thus in one instance, their amount was found, n a second bleeding, to have sunk from 62·8 to 49. The full proportion f fibrin in the blood of Chlorotic patients, seems to account for the infreuency of Hæmorrhage in them; whilst it also leads us to perceive that ey may be, equally with others, the subjects of acute Inflammation, hich we know to be the fact. A diminution of Corpuscles may also oexist with a diminution in the amount, or in the degree of elaboration,

* "Gazette des Hôpitaux," tom. vi. No. 90.

† The term *lymphatic* has been applied to this temperament; by which term was meant a redominance of lymph in the absorbent vessels.

of the fibrin; and this condition seems to be characteristic of Scrofula. Andral has noticed a diminution in the proportion of Red Corpuscles in other Cachectic states, resulting from the influence of various depressing causes on the nutritive powers; as in a case of Diabetes Mellitus, in which the patient was much exhausted; a case of Aneurismal dilatation of the Heart inducing Dropsy; and in several cases of Cachexia Saturnina. The proportion of Red Corpuscles seems constantly to undergo a marked diminution in Scurvy: and has been found, in some cases of this disease, as low as in intense Anæmia. The same may be said of the advanced stage of Bright's disease of the Kidney, and of 'Leucocythæmia.' A very rapid disintegration of the Red Corpuscles appears sometimes to take place, when a morbid poison is present in the blood, or when its composition has been seriously affected by the loss of its other constituents. Thus Dr. C. B. Williams * mentions a case of Albuminuria proving fatal in six days, with effusion of pus into the joints the day before death, in which the colouring matter was found to be dissolved in the liquor sanguinis, scarcely any perfect corpuscles being left. He has also observed a similar total destruction of the blood-discs in a case of malignant scarlatina with purpura; and has met with indications of a partial destruction of them in acute purpura connected with jaundice, and in cases of functional derangement of the liver.

175. A marked increase in the proportion of the *Colourless Corpuscles* has been frequently observed in the blood of Inflammatory subjects; this increase is not, however, so characteristic of the Inflammatory state as some have supposed; for it is by no means constant in that condition, and is frequently seen in very different states of the system (§ 196).—Attention has recently been drawn by Prof. J. H. Bennett † to a condition of the Blood, which is especially characterized by a marked excess of these bodies, and which he has designated by the term *Leucocythæmia* (white cell-blood). This condition has been detected in the blood of a considerable number of individuals suffering under diseases (most commonly enlargement) of the Spleen, Liver, and Lymphatic glands, either separately or in conjunction; but it has not yet been determined how far it is constantly associated with any of these abnormal conditions. In all cases in which the blood has been analyzed, its specific gravity has been found very low, and the total amount of solids small (being in one instance only 119 parts in 1000); but the fibrin is almost invariably above the average, having in one instance risen to 7·08. The total amount of Corpuscles is considerably reduced, having ranged in six analyses between 49·7 and 101·6, the average having been 82·36; and so large a proportion of the whole mass was in some instances determined by the microscope (no means being at present known, of physically separating these two orders of bodies) to be of the colourless kind, that the amount of *red* corpuscles must have been exceedingly small. The proportion of solids in the serum does not seem to undergo any decided alteration. No marked change in the condition of the blood could be observed during the progress of any of the cases which were under observation for long periods; and the circumstances under which the com-

* "Principles of Medicine," 2nd edit. p. 115.

† See his successive Papers in the "Edinb. Monthly Journal," for 1851.

mencement of this morbid perversion occurs, are still quite unknown. When the colourless corpuscles are present in very large amount, they give to the colourless coagula found in the heart and large vessels after death, a dull whitish colour, and render them very friable.

176. The quantity of *Albumen* in the blood seems to vary less than that of most of its other constituents. The proportion which it bears to the water of the serum, is of course elevated by anything which diminishes the latter; and thus we find it high in cholera after profuse discharges of fluid from the intestinal canal, and in other cases in which there has been an unusual drain upon the liquid part of the blood, provided that the albumen do not pass off with it, as sometimes happens. Where some special cause is in operation, which favours the escape of the albumen from the circulating current (as happens in various forms of Albuminuria, but especially in the advanced stage of 'Bright's disease'), the amount of albumen in the serum is reduced below the normal standard. Thus Dr. Christison found the entire solids of the serum to be reduced in some instances to 55 or even 52 parts in 1000, his estimate of their normal amount being 83·4; and he found the specific gravity of the serum to fall as low as 1020 or even 1019, the normal standard being from 1029 to 1031. According to Andral, the diminution in the amount of Albumen in the Serum is exactly proportional to the quantity contained in the Urine.*—The proportion of *fatty* matter in the serum, and especially of the cholesterin, has been found by MM. Becquerel and Rodier to undergo an increase at the commencement of most acute diseases; and they have also observed an increase of fat, and especially of cholesterin, in chronic diseases of the liver, in Bright's disease of the kidney, and in tuberculosis. The quantity of fat in the blood sometimes undergoes such an augmentation, as to give to the serum a constant 'milkiness.' This has been observed by Marcet in a case of diabetes, by Traill in hepatitis, by Christison in dropsy, icterus, and nephritis, by Zanarelli in pneumonia, and by Sion in mammary abscess. In Dr. Traill's case, the whole amount of solid matter in the serum was 211 parts in 1000; as much as 157 parts

* A case is related by Andral, under this head, which affords an interesting exemplification of the general facts that have been attained by his investigations. A woman who had been suffering from Erysipelas of the face, and who lost blood both by venesection and by leeches, became the subject of Albuminuria. The blood drawn at this time exhibited a considerable diminution in the proportion of Corpuscles, as well as of Albumen,—a fact which the previous loss of blood fully accounted for. After a short period, during which she had been allowed a fuller diet, another experimental bleeding exhibited an increase in the proportion of Corpuscles. Some time afterwards, when the Albumen had disappeared from the Urine, some more blood was drawn; and it was then observed that the Albumen of the Serum had returned to its due proportion, but that the Corpuscles had again diminished, whilst there was a marked increase in the quantity of Fibrin. This alteration was fully accounted for by the fact, that, in the interval, several Lymphatic ganglia in the neck had been inflamed and had suppurated; and that the patient had been again placed on very low diet. "Thus," observes Andral, "we were enabled to give a complete explanation of the remarkable oscillations which were presented, in the proportion of the different elements of the blood drawn at three different times from the same individual; and thus it is that, the more extended are our inquiries, the more easy does it become to refer to general principles the causes of all those changes in the composition of the blood, which, from the frequency and rapidity with which they occur, seem at first sight to baffle all rules, and to take place, as it were, at random. In the midst of this apparent disorder, there is but the fulfilment of *laws*; and in order to obtain these, it is only necessary to strip the phenomena of their complications, and reduce them to their simplest form."

being albumen, whilst 45 were fat. In Zanarelli's case, the blood contained so small a proportion of red corpuscles, that it seemed milky when it first flowed; and it did not undergo a regular coagulation, but merely separated into a thicker and a thinner portion. This blood only contained 95 parts of solid constituents in 1000; and 10 parts of these consisted of fatty matter, and 9 parts of extractive and salines; so that the whole amount of fibrin, corpuscles, and albumen was only 76 parts. In Dr. Sion's case, also, the blood itself was quite milky; it underwent no coagulation; and only a very small quantity of colouring matter was deposited when it was allowed to stand. This blood was found by Lecanu to contain 206 parts of solid constituents in 1000; but of these no less than 117 parts were fat, the remainder consisting of albumen (64 parts), and of extractive and salines (25 parts). No fibrin could be found, and the quantity of hæmato-globulin was inappreciable.* Such a fluid must be considered rather as chyle than as blood; and, in the entire absence of coagulating power, corresponds rather with chyle when first absorbed, than with that which is usually delivered by the thoracic duct (CHAP. VIII.).—Little is known with certainty regarding the variations of the *alkaline salts* in the blood in different diseases. The analyses which have been made, however, are considered by Prof. Lehmann † to indicate that in very severe inflammations they are very much diminished; whilst they are much increased in the acute exanthemata and in typhus, in dysentery, Bright's disease, and all forms of dropsy and hydræmia; and are often doubled in quantity in diseases depending upon malarious influences, such as endemic dysentery, malignant forms of intermittent fever, &c. Although a large quantity of saline matter usually passes off from the blood in Cholera, yet the proportion of water discharged is so much greater, that, as appears from the analyses of Dr. Garrod, the per-centage of salines in the blood is rather increased than diminished.‡

177. The proportion of *Water* in the blood will of course vary reciprocally with that of the solid constituents; and will be especially augmented when there is a marked diminution in the amount of red corpuscles. When there is an excessive and constant drain upon it, as in diabetes, there is at the same time such a craving for liquids, as causes the quantity ingested to supply the deficiency occasioned by its removal; so that the mass of the blood is not thereby diminished. In Cholera, however, the case is different; for in that form of the disease attended with copious discharges, the reduction in the liquid constituent of the blood becomes very marked, however large may be the quantity of water ingested. This is remarkably shown by the analyses of Lecanu,§ who found the proportion of solid constituents in some instances even to exceed that of the water.

| | | | | |
|---|---|---|---|---|
| Solid constituents . . . | 251 | 330 | 340 | 520 |
| Water . . . . | 749 | 670 | 660 | 480 |

No such degree of reduction has been observed by others; still the general fact is, that the proportion of water is considerably diminished.

* This remarkable case is cited in Simon's "Animal Chemistry," vol. i. p. 333, from the "Lancette Française," 1835, No. 49.

† "Lehrbuch der physiologischen Chemie," band ii. p. 242.

‡ "London Journal of Medicine," May, 1849.

§ "Etudes Chimiques sur le Sang," p. 106.

178. That the Blood is subject to a great variety of other morbid alterations, which are sometimes the causes, and sometimes the results, of Disease, cannot be for a moment doubted. But our knowledge of the nature of these changes is as yet very insufficient. The great amount of attention which is being directed by Chemical Pathologists to the subject, however, will doubtless ere long produce some important results.—Among the most frequent causes of depravation in the character of this fluid, we must undoubtedly rank the retention, in the Circulating current, of matters which ought to be removed by the Excreting processes. We shall hereafter see, that a total interruption to the excretion of Carbonic Acid by the lungs, will occasion death in the course of a very few minutes; and even when only a slight impediment is offered it, so that the quantity of carbonic acid always contained in arterial blood is augmented to but a small degree, a feeling of discomfort and oppression, increasing with the duration of the interruption, is speedily produced. The results of the retention of the materials of the Biliary and Urinary excretions will be hereafter considered (CHAP. XII.); and at present it will be only remarked, that such retention is a most fertile source of slight disorders of the system, that it is largely concerned in producing many severe diseases, and that, if complete, it will most certainly and rapidly bring about a fatal result.—The most remarkable cases of depravation of the Blood, by the introduction of matters from without, are those in which these substances act as *ferments*, exciting such Chemical changes in the constitution of the fluid, that its whole character is speedily changed, and its vital properties are altogether destroyed. Of such an occurrence, we have characteristic examples in the severe forms of Typhoid fever, commonly termed *malignant;* in Plague, Glanders, Pustule Maligne, and several other diseases; in some of which we can trace the direct introduction of the poison into the blood, whilst in others we must infer (from the similarity of result) that it has been introduced through some obscure channel, probably the lungs. The evidence which we possess of the 'intoxication' of the Blood, in these and other cases, derived from the perversion of the nutritive operations which it induces, will be considered in the next Section.

### 3. *Of the Vital Properties of the Blood, and its Relations to the Living Organism.*

179. It cannot be doubted that the perfect and regular performance of the various actions to which the Blood is subservient, is dependent upon the admixture of its principal components in their due proportions, and upon its freedom from deleterious matters, whether formed within the system, or introduced into the circulating current from without. And it is not difficult to see how any considerable alteration which affects its *physical* conditions merely, may thereby produce a most serious disturbance in the regularity of the circulation, and in the functions to which it ministers. Thus it has been shown by the experiments of Poisseuille, that a certain degree of viscidity is favourable to the motion of liquids through capillary tubes; a thin solution of sugar or gum being found to traverse them more readily than pure water will do. Hence any serious alteration in the proportion of the organic and saline compounds dissolved in the liquor sanguinis, and especially in that of the fibrin (on which the

viscidity of the blood appears chiefly to depend), might be expected to produce obstruction in the capillary circulation, and to favour transudation of the fluid portion of the blood; and the numerous experiments of Magendie* seem to favour this view, although they are far from manifesting that character for accuracy and discrimination, which would be required to afford an authoritative sanction to it. A much more determinate influence, however, must be exerted upon the red corpuscles, by any cause which seriously affects the specific gravity of the liquor sanguinis (§ 139); and the perfect elaboration of the albuminous constituent of the serum has been shown to be requisite, to prevent it from copiously transuding the membranous walls of the vessels which it traverses (§ 167).—These and other physical and chemical relations of the Blood, however, are quite subordinate to its Vital reactions; and it is into them that we have now to inquire.

180. There are only two constituents of the circulating Blood, which can be considered as being *themselves* endowed with *vital* properties; these are, the Fibrin and the Corpuscles. The remainder of its components can scarcely be looked upon in any other light than as *chemical* compounds, which are to be rendered subservient to the nutritive and other operations of the living tissues in virtue of *their* vitality, or which have already discharged their duty in the system. To attribute vital properties to a substance which, like Fibrin, is usually in a state of solution, has been considered by some Physiologists as an absurdity; but there seems no adequate reason why liquids, as well as solids, should not possess vital attributes; † and it has been already shown, that the power exhibited by fibrin, of spontaneously passing (under certain conditions) into an organized texture, however low its type, cannot be legitimately considered in any other light than as a vital endowment (§§ 26–29). That the Corpuscles, however, both Red and Colourless, are living cells, and that, like other cells, they possess vital endowments peculiar to themselves, is not now questioned by any one; and their separate history forms no unimportant element in the general 'Life of the Blood,' whilst it can scarcely be doubted, from the facts already stated, that it has a most important relation to the Life of the body generally.—Before proceeding, however, to inquire into the nature of this relation, our attention may be advantageously directed to that remarkable change in the state of the blood when withdrawn from the vessels of the living body, which is commonly known as its 'coagulation.' This term, however, as applied to the blood *en masse*, is quite inappropriate; since, as we shall presently see, the coagulation essentially consists in the passage of the fibrin alone from the soluble to the solidified state; and this component scarcely forms more than one hundredth part of the whole solid matter of the circulating fluid. All

* "Leçons sur les Phénomènes Physiques de la Vie."

† If, as the recent observations of Mr. Newport ("Phil. Trans." 1851, p. 241) appear to show, the spermatozoa in contact with the ovum undergo "diffluence" preparatory to the exertion of their fertilizing power, we have a most remarkable example of the possession, by a liquid, of endowments which must be considered as more purely *vital* than those of the spermatozoa themselves; for the latter, so long as they retain their organic form, manifest their vitality in no other way than by the performance of rhythmical movements. It would seem, in fact, as if the fertilizing material, prepared by the agency of the seminal cells, had been temporarily cast into the solid form, for the sake of enabling it to find its way, by spontaneous movement, to the ovum it is destined to impregnate.

he phenomena attendant upon this process, and the conditions by which is influenced, have been made the subject of very careful study, both y Chemists and Physiologists; but it must be admitted that they throw ery little light upon the vital relations of the Blood to the Organism at rge, these being only sustained whilst it is circulating in a fluid state, nd being interfered with by anything that favours its passage into the rm which it assumes when withdrawn from the body.

181. The *Coagulation of the Blood*, then, consists in the new arrangement of its constituents, which takes place when it is drawn from the essels and is left to itself, or when the body itself dies (§ 138). This ew arrangement essentially depends upon the passage of the Fibrin from e soluble to the insoluble state, in which it forms, not an amorphous agulum, but a network of fibres more or less definitely marked out § 26–28); in the meshes of which network are included the Red coruscles, usually grouped together in columnar masses, resembling piles of oney. The Crassamentum or Clot thus formed, becomes dense, in roportion to the amount of Fibrin which it contains, and to the degree its elaboration; and it undergoes a gradual contraction, by which the lbuminous, Saline, and Extractive matters, still dissolved in the water, e more or less completely expelled from it, constituting the Serum. his separation will not occur, however, if the coagulation take place in a allow vessel; nor if the amount of Fibrin should be small, or its vitality w. A homogeneous mass, deficient in firmness, presents itself under ch circumstances; though the solid part of this may pass into a state more complete condensation, after the lapse of a certain time.—That e coagulation is due to the Fibrin, and that the Corpuscles do not take y active share in the process, appears from several considerations.* A icroscopical examination of the Clot shows, that it has the same texture ith Fibrin when coagulating by itself; the Corpuscles clustering together the interspaces of the network, and not being uniformly diffused rough the whole mass. Their specific gravity being greater than that the Fibrin, they are usually most abundant at the lower part of the ot; and the upper surface is sometimes nearly colourless, especially hen the coagulation has taken place slowly; yet this upper part is much mer than the under, showing that the Fibrin alone is the consolidating ent. If, after the complete subsidence of the Corpuscles, a little of the lourless Liquor Sanguinis be skimmed off, it will undergo complete agulation, forming a colourless clot; as was long ago shown by Hewson. he same fact may be experimentally demonstrated by the use of methods hich effect an artificial separation of the Fibrin from the Corpuscles. hus Müller placed the blood of a Frog, diluted with water (or still tter, with a very thin syrup) on a paper filter, of sufficiently fine texture keep back the Corpuscles; and the Liquor Sanguinis, having passed rough the filter completely unmixed with them, presented a distinct agulum, although, from the diluted state of the fluid, this did not ssess much consistency. Owing to the more minute size of the Blood-

* It is remarkable that this doctrine, clearly established by the older Physiologists, and pecially by Hewson, should ever have been put aside, even temporarily, for the untenable pothesis that the coagulation of the blood is due to a running-together of its red corpuscles. r an admirable summary of the history of opinion on this subject, see Mr. Gulliver's Introction to his Edition of Hewson's works (published by the Sydenham Society).

discs of warm-blooded animals, this experiment cannot be so readily performed with their blood. So, again, if fresh-drawn blood be continually stirred with a stick, the Fibrin will adhere to it in strings during its coagulation; and the Red corpuscles will be left suspended in the serum, without the slightest tendency to coagulate. Moreover, if a solution of any salt, that has the property of retarding the coagulation (such as carbonate of potash or sulphate of soda), be added to the blood, the Corpuscles will have time to sink to the lower stratum of the fluid, before the clot is formed; the greater part of the crassamentum is then entirely colourless, and is found by the microscope to contain few or no red particles. It will be presently shown, however, that the difference of specific gravity is by no means the only cause of the separation of the Corpuscles from the Liquor Sanguinis (§ 189).

182. That the Coagulation of the Blood is not, as some have supposed, a proof of its death, but is rather an act of vitality, appears evident from what has been already stated (§ 27) of the incipient organization which may be detected even in an ordinary clot; and still more from the fact that, if the effusion of Fibrin take place upon a living surface, its coagulation is the first act of its conversion into solid tissues which become constituents of the living fabric. It is absurd to suppose that the Blood dies, in order to assume a higher form. A complete demonstration of the truth of the Hunterian doctrine, that the Blood might become organized, like plastic exudations of "coagulable lymph," has been afforded by the researches of Dr. Zwicky,* on the changes occurring in the clots of blood which form in blood-vessels, above the points where they have been tied. He has traced the successive stages of the metamorphosis of the coagulum into fibro-cellular tissue, and the formation of vessels in its substance; the whole process taking place exactly as in an inflammatory exudation, and the blood-corpuscles exerting no other influence upon it, than that of slightly retarding it. Similar observations have been made by Mr. Paget.†

183. Instances occasionally present themselves, in which the Blood does not coagulate after death, or coagulates very imperfectly. It was affirmed by Hunter‡ that no coagulation occurs in the blood of animals hunted to death, or of those killed by lightning, by electric shocks, or by blows upon the epigastrium; and this statement has been generally received upon his authority. It is far, however, from being constantly true; for Mr. Gulliver has collected numerous cases in which coagulation was found to have taken place in the blood of animals killed in each of these modes; in some of them, however, the coagulation was very imperfect.§ It is not improbable that some of the instances of apparent *absence* of coagulation, were really cases of *retarded* coagulation (§ 184); and Dr. Polli goes so far as to maintain that the complete absence of coagulating power is a phenomenon which has no real existence. He states that he has never met with an instance in which the

* "Ueber die Thrombus;" Zurich, 1846.

† See his 'Lectures on the Processes of Repair and Reproduction,' in the "Medical Gazette" for 1849, vol. xliii. p. 1066.

‡ "The Works of John Hunter," edited by James F. Palmer, vol. iii. pp. 34, 114.

§ See "Edinb. Med. and Surg. Journ." Oct. 1848, pp. 367, 418; and his Edition of "Hewson's Works," pp. 20, 21.

lood, when left to itself, and duly protected from external destructive nfluences, did not coagulate before becoming putrid; and that he has nore than once found blood to coagulate, which had been taken in a uid state from the vessels thirty-six or forty-eight hours after death.* till there seems no reasonable doubt that non-coagulation may occur, hen the blood has been previously subjected to conditions which affect ie vitality of its fibrin. Such is often the case, for example, when eath occurs from Asphyxia, as by hanging, drowning, or breathing of respirable gases;† and the same has been observed in cases of poisoning y hydrocyanic acid, in which asphyxia seemed to have been the imme- iate cause of death. In certain diseased states, again, we have seen that ie coagulating power seems to be completely deficient (§ 173).

184. The length of time which elapses before Coagulation, and the egree in which the clot solidifies, vary considerably; in general, they e in the inverse proportion to each other. Thus, if a large quantity of ood be withdrawn from the vessels of an animal at the same time, or ithin short intervals, the portions that last flow coagulate much more pidly, but much less firmly, than those first obtained. In blood drawn uring Inflammatory states, again, the coagulation is usually slow, but e clot is preternaturally firm; especially at its upper part, where the uffy coat (§ 189) or colourless stratum of fibrin, gradually contracts, d produces the *cup*, which may be generally considered to indicate a high gree of Inflammation. Although the Blood withdrawn from the body agulates (except under the peculiar circumstances just stated) whether be kept at rest or in motion, whether its temperature be high or low, d whether it be excluded from the air, or be admitted to free contact ith the atmosphere, yet its coagulation may be accelerated or retarded variation in these conditions.—If the blood be continually agitated a bottle, its coagulation is delayed, though it will at last take place in reds or insulated portions; but that *rest* is not the cause of its coagu- tion (as some have supposed), is proved by the fact that, if a portion of ood be included between two ligatures in a living vessel, it will remain uid for a considerable time;‡ as it also will when effused into the midst living tissues, or kept in a state of stagnation in parts affected with flammation. Thus Mr. Gulliver, besides other instances, mentions a markable case witnessed by himself, in which a collection of blood ich had been effused in consequence of a bruise on the loins, was und uncoagulated when let out twenty-eight days afterwards; it mea- red five ounces, was as liquid as blood just drawn from a vein, and owed the normal characters when examined microscopically; and it agulated in a cup in less than thirty minutes (Op. cit. p. 17). And r. Paget mentions that he has known the blood remain fluid in the ssels of an inflamed part, though in a state of complete stagnation,

* "Annali Universali," 1845; and "Ranking's Abstract," vol. ii. p. 337.

† See Dr. J. Davy's "Physiological and Anatomical Researches," vol. ii. p. 192.

‡ The testimony of all experimenters is in accordance on this point, although they differ to the length of time that elapses before coagulation commences. Mr. Gulliver states that of many trials made by him, the coagulation commenced within two hours in only a instances; more commonly, three, four, or five hours elapsed before any clot was formed; 1 in one instance the coagulation was incomplete at the end of twenty-four hours. In all se experiments, the blood coagulated in the course of a few minutes, when withdrawn m the living vessel. See Mr. Gulliver's edition of "Hewson's Works," p. 23.

for as long as three days.*—Again, the coagulation is accelerated by moderate warmth, the natural heat of the body from which the blood is taken appearing to be most favourable to it; but the coagulating power appears to be destroyed by a temperature of about 150°, blood heated to that point remaining permanently fluid. (Gulliver, Op. cit. pp. 4, 5.) On the other hand, the coagulation is retarded by cold; but the coagulating power is not destroyed even by extreme cold; for if blood be frozen immediately that it is drawn, it will coagulate on being thawed.—Moreover it is accelerated by exposure to air, but it is not prevented by complete exclusion from it, as is proved by its taking place in a vacuum, or in a shut sac within the dead body: complete exclusion from the air, however, retards the change; as has been shown by causing blood to flow into a vessel containing oil, which will form an impervious coating on its surface, and will occasion the coagulation to take place so slowly, that the red particles have time to subside, and the upper stratum of the clot is colourless.†—The effect of the addition of strong solutions of neutral salts to fresh blood, is usually to retard, and sometimes even to prevent, its coagulation; and the same effect is produced by many vegetable substances, particularly those of the narcotic and sedative class, such as opium, belladonna, aconite, hyoscyamus, digitalis, and tea or coffee in strong infusion.‡ The action of most of the substances, however, which preserve the fluidity of the blood, only continues during such time as their solutions retain a certain strength; for if they be diluted, coagulation will then take place, although in most cases less perfectly than it would have done at first. There appears to be no limit to the time during which the coagulation may be thus postponed; thus Mr. Gulliver§ mentions that he has kept horse's blood fluid with nitre for fifty-seven weeks, and that it still readily coagulated when diluted with water (Op. cit. p. 12).—It is not so difficult, therefore, as it might otherwise seem, to give credit to the statement of Dr. Polli, that, in a case witnessed by himself, complete coagulation of the blood did not take place until fifteen days after it had been withdrawn from the body; and that fifteen days more elapsed, before putrefaction commenced in it. The upper four-fifths of the clot were colourless, the red corpuscles occupying only the lowest fifth. It is additionally remarkable, that the patient (who was suffering under acute pneumonia), being bled very frequently during the succeeding week, the blood gradually lost its indisposition to coagulate.||

* 'Lectures on Inflammation,' in "Medical Gazette," 1850, vol. xlv. p. 971.

† Dr. Babington in "Medico-Chirurgical Transactions," vol. xvi.

‡ See Dr. J. Davy's "Anatomical and Physiological Researches," vol. ii. pp. 101, 102; and Mr. Prater's "Experimental Inquiries in Chemical Physiology," pp. 59, 63, &c. A copious table of the results of their experiments is given in Mr. Ancell's 'Lectures on the Physiology and Pathology of the Blood,' in the "Lancet" for Dec. 21, 1839.

§ Mr. Gulliver considers this fact, together with the occurrence of coagulation on the thawing of blood which has been frozen whilst yet fluid, as conclusive against the *vital* character of the act; remarking that if we believe the coagulation to be an effect of life, we must admit that we can freeze and pickle the life (Op. cit. p. 21). No such admission, however, is necessary. We do not freeze and pickle the life; but we simply preserve the vital properties of the substance by preventing it from undergoing spontaneous change; thus doing the same for the blood, as may be done for seeds, eggs, and even highly organized bodies, which may be kept in a state of 'dormant vitality' for unlimited periods, by cooling or drying them, or by secluding them from the atmosphere. (See "Princ. of Phys., Gen. and Comp.," CHAP. III., Sect. 4.)

|| "Gazetta Medica di Milano," Genn. 20, 1844; cited in Mr. Paget's 'Report' in "Brit. and For. Med. Rev." vol. xix. p. 252.

185. It has been maintained by some observers, that a certain amount ›f heat is liberated during coagulation; but this idea would seem to have ›een founded on a fancied analogy between coagulation and freezing; ud it is negatived by the careful observations of Hunter, Schroeder Van ler Kolk, J. Davy, and Denis.—Again, it has been asserted that the act ›f coagulation is attended by the extrication of a small quantity of arbonic acid; but there is no sufficient proof that blood in coagulating ;ives out more carbonic acid than it ordinarily does by exposure to the .ir (§ 163). Moreover, it has been shown by the experiments of Sir I. Davy* and Dr. J. Davy,† that no effect is produced, either in accele-ating or retarding coagulation, by placing blood in an atmosphere of .itrogen, nitrous gas, nitrous oxide, or carbonic acid; and it has been ɔund that coagulation still takes place, even if the blood be agitated with arbonic acid.

186. The vital condition of the walls of the blood-vessels appears to ave an important influence upon the fluidity of the blood. Thus it has een found by Sir A. Cooper and Mr. Thackrah, that whilst blood in-losed in a *living* vein retained its fluidity for some time, blood similarly nclosed in a *dead* vein, the atmosphere being completely excluded, oagulated in a quarter of an hour. Moreover, inflammation of the walls f the blood-vessels (which is a condition of *depressed* vitality, CHAP. XI. ECT. 3) promotes the coagulation of the blood which they contain; and ıus it is, that the trunks both of arteries and veins frequently become hoked up by coagula.‡ Moreover, although there can be no doubt that large proportion of the loose fibrinous masses found in the heart and ırge vessels after death are the result of post-mortem coagulation, yet ıere is adequate evidence, derived from the symptoms observed during fe, and from the appearances presented by the coagula themselves, that ıe coagulation has commenced during life; and in all cases of this kind, ıere has been a marked depression of vital power for some time pre-ious to the final extinction of life. Again, it was found by Schrœder an der Kolk,§ that if the substance of the brain and spinal marrow be roken down, coagulation of the blood takes place whilst it is still ıoving within the vessels; clots being found in them, even within a few ıinutes after the operation. Further, that the contact of a dead sub-

* "Researches on Nitrous Oxide," pp. 380–1.

† "Anatomical and Physiological Researches," vol. ii. p. 71.

‡ It was observed by Hunter, and has been frequently noticed since, that when amputation performed on account of spontaneous gangrene of the lower extremities, there is no jet of ood from the divided arterial trunk, which is obstructed by coagulum far above the line to hich the gangrene has extended; and there is good reason to regard the gangrene as, in ıese cases, the result of a previous arteritis, which has thus put a stop to the circulation ırough the limb. (For evidence in support of this doctrine, see the "Essai sur les Gan-ènes spontanées" of M. François, Paris, 1832.) The author, whilst a pupil at the Mid-lesex Hospital in 1835, witnessed a remarkable case of Phlebitis (apparently brought on by ıppressed menstruation), in which both femoral veins were successively affected, and in hich death took place suddenly when the patient appeared to be recovering from the attack; ı post-mortem examination, not only the iliac trunks, but also the vena cava, for some stance above their junction, were found to be completely obstructed by nearly colourless agula adherent to their walls; so that the wonder was, how any return of blood could ıve taken place from the pelvis and lower extremities. There seemed no reason to attri-ıte the formation of these coagula to the introduction of pus into the venous circulation.

§ "Comment. de Sanguinis Coagulatione," Groeningen, 1820.

stance promotes coagulation, even in the living and actively moving blood, is shown by the experiments of Mr. Simon, who carried a single thread (by means of a very fine needle) transversely through an adjacent artery and vein of a dog, and left it there, so that it might cut the stream, for a period of from twelve to twenty-four hours; the consequence of which was, that a coagulum was formed upon the thread, more or less completely obstructing the vessel. There was, however, a marked difference in the coagula formed within the artery and the vein respectively, which may be attributed to the difference in the quality of the fibrin in the blood of the two vessels (§ 164), or to the difference in the rate of its motion, or to both causes conjointly; for the thread which traversed the artery usually presented a 'vegetation' on its surface, sometimes as large as a grain of wheat, always of a pyramidal shape, with its base attached to the thread, and its apex down-stream; whilst the venous coagulum was a voluminous black clot, chiefly collected on that side of the thread remotest from the heart.*

187. Again, the contact of dead animal matter with the blood appears to promote the coagulation of its fibrin in a very remarkable degree; occasioning coagula to form whilst it is yet actively moving in the vessels of the living body. Thus M. Dupuy found that the injection of cerebral substance into the veins of an animal, occasioned its death almost as instantaneously as if prussic acid had been administered; the circulation being rapidly brought to a stand by the formation of voluminous clots in the heart and large vessels. These experiments were repeated and confirmed by M. de Blainville.†—The same effect is produced with still more potency, when the substance injected is rather undergoing degradation, than actually dead; for it then seems to act somewhat after the manner of a ferment, producing a marked diminution in the vitality of the solids and fluids with which it may be brought in contact. Such is pre-eminently the case with *pus*, as was long since observed by Hunter, and as Mr. H. Lee has lately determined more precisely. It was found by the latter, that healthy blood received into a cup containing some offensive pus, coagulated in *two* minutes; whilst another sample of the same blood, received into a clean vessel of similar size and shape, required *fifteen* minutes for its complete coagulation. When he injected putrid pus into the jugular vein of a living ass, coagulation took place so instantaneously as to produce an immediate obstruction to the current of blood, so that the vessel at once acquired a cord-like character; and in this mode the

* "Lectures on General Pathology," p. 56. Mr. Simon applies this fact to the explanation of the 'vegetations' which so commonly present themselves upon the valves of the heart, in cases of rheumatic endocarditis; maintaining that they are simple deposits from the fibrin of the blood, which is unusually abundant in this condition. This doctrine can only be substantiated, however, by a careful microscopic examination of these substances; and if they should be proved to have the simple constitution which Mr. Simon imputes to them, the fact will in no degree set aside (as he seems to consider it must do) the existence of endocardial inflammation, but will rather confirm it, since the deposition of fibrin on those particular spots is likely to be specially determined by inflammation of the subjacent membrane.

† "Gazette Médicale," 1834, p. 521. There is no reason to suppose that cerebral substance possesses a more special influence, than would be exerted by any other tissue which could be as easily mixed up with the circulating current. It will be remembered that the presence of a piece of flesh, or of the clot of blood, determines the coagulation of fibrin in a solution from which it would not otherwise have separated (§ 26).

pus was usually prevented from finding its way into the general current of the circulation. Whilst it thus remains circumscribed by a coagulum of blood, the pus so introduced seems to produce no other constitutional disturbance than is attributable to the local injury; but if the circumscription should be incomplete, and the pus should be carried into the general circulation, it becomes a source of extensive mischief, determining the formation of abscesses in various parts, and producing a most depressing influence on the system at large.* — The effect of certain animal poisons of a still more potent nature, when introduced into the current of the circulation (as by the bite of venomous serpents), appears to be, like that of a high temperature, the entire *destruction* of the coagulating power of the blood, as well as of the vital endowments of the tissues generally (§ 115).

188. The proportions of Serum and Clot which present themselves after coagulation, are liable to great variation, independently of the amount of the several ingredients characteristic of each; for the crassamentum may include, not only the fibrin and red corpuscles, but also a large proportion of the serum, entangled as it were in its substance. This is particularly the case when the coagulation is rapid; and the clot then expels little or none of it by subsequent contraction. On the other hand, if the coagulation be slow, the particles of fibrin usually seem to become more completely aggregated, the coagulum is denser at first, and its density is greatly increased by subsequent contraction. When a firm fresh clot is removed from the fluid in which it is immersed, its contraction is found to go on increasing for 24 or even 48 hours, serum being squeezed out in drops upon its surface; and in order, therefore, to form a proper estimate of the relative proportions of Crassamentum and Serum, the former should be cut into slices, and laid upon bibulous paper, that the latter may be pressed from it as completely as possible.—According to the experiments of Mr. Thackrah,† coagulation takes place sooner in metallic vessels than in those of glass or earthenware, and the quantity of serum separated is much less; in one instance, the proportion of serum to clot was as 10 to $24\frac{1}{2}$, when the blood coagulated in a glass vessel; whilst a portion of the same blood, coagulating in a pewter vessel, gave only 10 of serum to 175 of clot. The specific gravity of Blood is no measure of its coagulating power; for a high specific gravity may be due to an excess in the amount of corpuscles, which form the heaviest part of the blood; and may be accompanied by a diminution in the quantity of fibrin, which is the coagulating element.

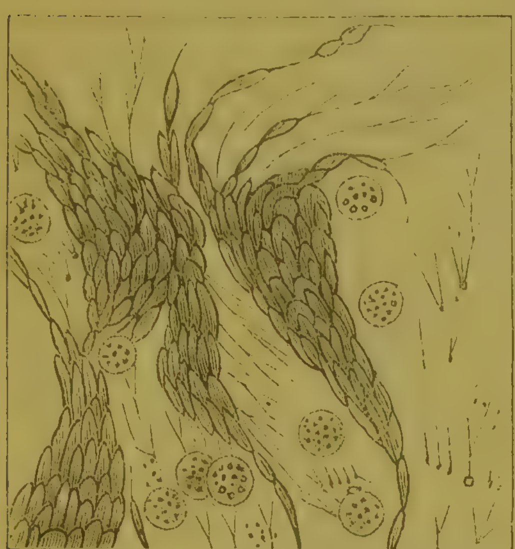
189. The surface of the Crassamentum not unfrequently exhibits, in certain disordered conditions of the blood, a layer that is nearly free from colour; and this is known as the *Buffy Coat.* The presence of this has been frequently regarded as a sign of the existence of Inflammation, indicating an undue predominance of fibrin; but this idea is far from being correct, since, as will presently appear (§ 190), it may result from an opposite condition of the blood. A similar colourless layer is usually observable, when the coagulation of the blood has been retarded by the addition of agents that have the power of delaying it (§ 184); and since, in

* See Mr. H. Lee's excellent Treatise "On the Origin of Inflammation of the Veins, and on Purulent Deposits."

† "Enquiry into the Nature and Properties of the Blood," 2nd edit., p. 66.

inflammatory states of the system, the blood is generally long in coagulating, it has been supposed that the separation of the red particles from the fibrinous parts of the clot is due to this cause alone. It was long since pointed out by Dr. Alison,* however, that this explanation is insufficient, for the two following reasons:—" 1. The formation of the buffy coat, though no doubt favoured or rendered more complete by slow coagulation, is often observed in cases where the coagulation is more rapid than usual; and the colouring matter is usually observed to retire from the surface of the fluid in such cases, before any coagulation has commenced. 2. The separation of the fibrin from the colouring matter in such cases takes place in films of blood, so thin as not to admit of a stratum of the one being laid above the other; they separate from each other laterally, and the films acquire a speckled or mottled appearance, equally characteristic of the state of the blood with the buffy coat itself."—Now we have already seen that the red corpuscles of healthy blood have a tendency to aggregate together in piles and masses; and it has been pointed out by Prof. H. Nasse † and Mr. Wharton Jones,‡ that this tendency is greatly augmented in inflammatory blood, so that the corpuscles run together into little clumps often visible to the naked eye, and adhere to each other with considerable tenacity. Further, it has been shown by Mr. Gulliver,§ that the subsidence of the red corpuscles is more rapid in inflammatory than it is in healthy blood, and that their rate of sinking increases with their aggregation; so that whilst they sink about an eighth of an inch during the first two or three minutes, they sink through five or six times that space in the next interval of the same length. That the quickness with which they thus aggregate in the lower part of the clot, does not depend (in the case of inflammatory blood) upon the mere facility with which they sink, was further determined by the use of means which tended to diminish or increase their aggregation; thus it was found that the addition of weak saline solutions, by which the liquor sanguinis is attenuated, but which diminish the mutual attraction of the red corpuscles, partially or completely prevented the formation of the buffy coat, in blood which exhibited it strongly when left pure, even though its coagulation was considerably retarded thereby; on the other hand, the addition of

FIG 13.



The microscopic appearance of a drop of Blood in the Inflammatory condition. The *red* corpuscles lose their circular form, and adhere together; the *white* corpuscles remain apart, and are often more abundant than usual.

* " Outlines of Physiology," 3rd edit. p. 89.

† " Das Blut," cited in Henlé's " Anatomie Générale" (traduit par Jourdan), p. 468.

‡ ' Report on Inflammation,' in " Brit. and For. Med. Rev." vol. xvii. p. 567.

§ See his Memoir ' On the Buffy Coat of the Blood,' in the " Edinb. Med. and Surg. Journ." No. 165; and his edition of " Hewson's Works," p. 41.

mucilage with a small quantity of saline matters, the effect of which is to promote the aggregation of the corpuscles, tended to develope the buffy coat by increasing the rate at which they sink. Now as it has been found that liquor sanguinis deprived of its corpuscles coagulates more slowly than unaltered blood, it does not seem improbable, as Mr. Gulliver has remarked, that this separation of the two components of the crassamentum, which determines the formation of the buffy coat, is the cause, rather than the consequence, of the slowness of the coagulation of inflammatory blood.—It is in the buffy coat of inflammatory blood, that we see the clearest indications of organization ever presented by the circulating fluid. The fibrous network is frequently extremely distinct; and it commonly includes a large number of colourless corpuscles in its meshes, these, indeed, being sometimes so numerous, that it is almost entirely composed of them. In its Chemical Composition, the buffy coat of inflammatory blood appears to be peculiar; containing a larger or smaller amount of the substance, readily soluble in boiling water, which is considered by Mulder to be the tritoxide of proteine (§ 30).

190. When the 'buff' arises from other causes, however, its appearance is less characteristic. It appears from the researches of Andral, that the usual condition of its production is an increase in the quantity of fibrin in proportion to the red corpuscles, and not a simple augmentation of fibrin. This increase may occur in two ways;—either by an absolute increase in the fibrin, the amount of the corpuscles remaining unchanged, or not being augmented in the same proportion;—or by a diminution of the corpuscles, the quantity of fibrin remaining the same, or not diminishing in the same proportion. Hence in severe Chlorosis, in which the latter condition is strongly developed (§ 174), the buffy coat may be as well marked, as in the severest Inflammation.* Unless the composition of the blood be altered in one of these two ways, it is stated by Andral that the buffy coat is never formed; the influence of circumstances which favour it, not being sufficient to produce it when acting alone. The absence of these circumstances may prevent it, however, when it would otherwise have been formed; thus, when the blood flows slowly, the 'buff' is not properly produced; because the slow discharge gives one portion time to coagulate before another; and only the blood last drawn furnishes the

* The records of Medicine scarcely furnish a more notable example of the pernicious influence of theories founded upon a shallow empiricism, and of the superiority of a rational practice based on a knowledge of the real facts of the case, than is afforded by the contrast between the former and the present treatment of Chlorosis. Whilst the notion prevailed that the buffy coat is a sign of Inflammation, and that the most powerful remedy for Inflammation is loss of blood, patients already reduced to a state of anæmia, who complained of pain in the left hypochondrium, palpitations, &c., were bled over and over again, every withdrawal of blood of course seriously increasing the mischief, by producing a further reduction in the proportion of red corpuscles (§ 162). The author well remembers that, when a pupil in the Bristol Infirmary in the years 1833–4, he was repeatedly directed by the estimable Senior Physician (long since dead) to draw eight, ten, or twelve ounces of blood from patients in this condition; and that the crassamentum, after coagulation, often resembled a small island floating in an ocean of serum. Yet, because this minute clot exhibited the buffy coat, the bleeding was considered to be 'orthodox' practice, and the obstinacy of the anæmic state was attributed to the severity of the disease. If M. Andral had made no other contribution to Medical Science, than the demonstration of the real nature of this condition of the blood, and of the influence of further withdrawal of that fluid in promoting it, he would have rendered a most essential service to the multitudes of females who are unfortunate enough to suffer from this kind of deterioration of their vital fluid.

fibrin at the upper part of the vessel. Again, in a deep narrow vessel, the 'buff' will form much more decidedly than in a broad shallow one; because the thickness of the fibrinous crust will be greater.

191. It appears, then, from the foregoing facts, that we must regard the coagulation of the blood as essentially dependent upon the vital properties of its *Fibrin;* the tendency to aggregation which is exhibited by the Red Corpuscles, having no special part in it, except when that tendency is abnormally augmented, and then only influencing the relative situations of the two components of the clot. The deficiency in coagulating power, by which the blood is sometimes marked, must be attributed to the want of due elaboration in the Fibrin alone, or to the destruction of its vital endowments by some agent which has a noxious influence upon it; of the former condition we seem to have an example in such a case as that already cited (§ 176), in which the circulating fluid consisted of a very crude chyle; of the latter, in those diseased states in which we can trace the operation of a poison upon blood that was previously healthy, as when asphyxia has occasioned the retention of carbonic acid generated within the system, or when the *materies morbi* of cholera or some malignant fever has been introduced into the circulation. But it would be by no means fair to attribute the noxious influence of such poisons solely to their power of destroying the coagulability of the blood-fibrin, for it is obviously exerted in many other ways; and it is probable that the same agency which kills the fibrin, exerts a similar destructive power on the vitality of the corpuscles, and on that of the tissues through which the poisoned blood circulates.—But whilst we attribute the coagulating power of the Blood to the vital endowments of the fibrin, we can scarcely fail to perceive that the exercise of this power is kept in check (so to speak) by the vital endowments of the living tissues with which it is in contact. For, as we have seen, the main condition of coagulation is the diminution or cessation of their agency, either by the withdrawal of blood from the body, or by the death of the organism enclosing it, or by the lowered vitality of the tissues through which it moves (§ 186); whilst mere stagnation exerts but a secondary influence upon it (§ 184). And thus we seem entitled to say, that the liquid condition of the fibrin is a result of a balance of forces between the fibrin and the living tissues, those of the former tending to its solidification, whilst those of the latter maintain its fluidity; but that if the latter should be deficient, the former come into uncontrolled action, and expend themselves in the production of a lowly-organized tissue, the higher vitalization of which depends upon subsequent operations (§ 29). The source of this vital endowment of the Fibrinous constituent of the blood, must be looked-for in the operations to which the crude albuminous pabulum is subjected, after its first reception into the system; and these will hereafter become the subject of inquiry.

192. Of the particular purposes which are served by the Fibrin of the blood in the vital economy of the system at large, it must be confessed that we have but little positive knowledge. The idea has been entertained by many Physiologists (including the Author of this treatise) that the fibrin is that element of the blood which is immediately drawn-upon in the operations of nutrition; being the intermediate stage between the crude albumen and the solid tissues. This opinion rested in part upon

.e current doctrine, that fibrin is the constituent of Muscle; and in ırt upon the assumption, that, as fibrin is more endowed with vital ·operties than any other of the liquid components of the blood, so as to capable of passing by itself into the condition of an organized tissue, must be the one most readily appropriated by the various parts of the lid fabric, as the material for their growth and development.—Various nsiderations have of late been adduced, however, which tend to shake is belief. It has been shown that so far from there being any evidence the identity of the fibrin of blood and the substance of muscle, the idence is precisely the other way (§ 25). Again, we have seen that ere are both structural and chemical indications, that fibrin is in a ıte of transition rather towards the fibro-gelatinous textures, than wards those of the cellulo-albuminous type; for the fibrous network ıich is formed by its coagulation bears a greater resemblance to the ıite fibrous tissue (§ 220), than to any other texture of the body; whilst e points in which the chemical properties of fibrin differ from those of umen, are such as manifest a relationship to gelatin (§§ 25—30). We em justified in regarding it, then, as the special pabulum of those *nnective* tissues, whose physical offices in the economy are so important, ıilst their vital endowments are so low (CHAP. V. SECT. 1); and as ving, by its own formative power, for the generation of these tissues, erever and whenever there may be a demand for them.—On the other nd, there is a complete absence of evidence, that the fibrin of the ood serves any special purpose in the nutrition of the cellulo-albuminous sues; and there are various negative indications that their generation d development do not depend upon its presence. For, in the first ıce, there is evidence that a fluid destitute of coagulating power may ve the general purposes of nutrition; this being furnished, not merely such cases as that just alluded to (§ 176), in which the circulat- fluid was entirely deficient in fibrin, apparently from defective ela- ation; but also by the results of experiments on the introduction of ibrinated blood into the vessels of animals which had been reduced to ıcope by the withdrawal of blood, it having been found by Dieffen- ch* and Bischoff,† that this operation immediately restored the heart's ion, and, with it, the general train of vital operations. Further, hough we are not justified in positively affirming that the fluid which nsudes the walls of the capillary blood-vessels, for the nutrition of tissues which they supply, is albuminous rather than fibrinous, yet re seems a strong probability that such is the case; all non-inflam- tory exudations being albuminous, unless produced by an excess of ssure (§ 227); and the fluid of the lymphatics, which is probably re-collected surplus of that which has thus escaped, being so slightly gulable, that we may fairly regard the presence of fibrin in it as result of the elaboration which it has undergone during its pas- e through the absorbent system. Moreover, the formation of the getable cell takes place at the expense of an albuminous fluid, there ng no element in the juices of the Plant analogous to the fibrin of blood; and although the endowments of certain parts of Plants are peculiar (§ 125), as to prevent any such argument from possessing

* "Die Transfusion des Blutes," Berlin, 1828. † "Müller's Archiv.," 1835.

much weight, yet when it is considered that the great mass of the Vegetable fabric grows (like that of Animals) at the expense of nutriment already prepared for it, and that the composition of the Vegetable cell is essentially the same as that of the Animal cell (§ 99), the fact of the entire absence of any substance at all resembling fibrin in the vegetable juices, and the corresponding deficiency of fibro-gelatinous tissues in their solid fabric, may be adduced in confirmation of the views here advanced.

193. Even if, however, we thus limit the value of Fibrin, as regards the ordinary nutritive processes, to the maintenance of the gelatigenous tissues, we still have to consider it as a most important component of the blood, and as altogether different, in its relations to the living body, from those products of disintegration which are destined to excretion (§ 29, *note*). For, putting aside its presumed importance in maintaining that physical condition of the blood which is most favourable to its free movement through the vessels, and to its due retention within their walls (§ 179), we find that it is entirely on the coagulating powers of the blood, that the cessation of hæmorrhage even from the most trifling injuries, is dependent; that the limitation of purulent effusions by the consolidation of the surrounding tissue, and the safe separation of gangrenous parts, can only take place in virtue of the same property; and that the adhesion of incised wounds, still more the filling-up of breaches of substance, require as their first condition, that either the blood, or matter exuded from it, should be able to assume the state of fibrous tissue.—The results of *deficiency* of coagulating power in the blood, are fearfully seen in that continued and uncontrollable flow which takes place in Purpura, the blood not being able to form a clot sufficient to fill up even the wound made by the scratch of a pin; in the want of circumscription of collections of pus within an abscess, allowing its infiltration through tissues that were previously healthy, and thus occasioning a wide-spread destruction of organized texture, which is characteristic of certain forms of inflammation (this result being usually attributable either to the previously unhealthy condition of the system, or to the introduction of some specific poison into the blood); in the want of a corresponding limitation between the living and the dead parts in gangrene, so that hæmorrhage takes place on the separation of the slough, the vessels not having been previously obstructed by coagula; and in the entire absence of any effort, either by simple adhesion, or by the formation of connective tissue, whereby the sides of open wounds may be kept together, and dissevered parts brought again into connection (See CHAP. XI. SECT. 2).—On the other hand, we see the consequences of *excess* of the proportion of fibrin, and of that increased plasticity (or tendency to fibrillate) which usually accompanies its augmentation, in the tendency to form those plastic effusions which are characteristic of the Inflammatory state, and which, if poured out upon serous or mucous surfaces, constitute 'false membranes' and 'adhesions,' or, if infiltrated into the substance of living tissues, occasion their consolidation. This increased plasticity of the blood, however, may frequently be regarded in the light of an 'effort of Nature,' to antagonize the evil consequences of that depression or positive destruction of the vitality of the solid tissues, which seems to form an essential part of the inflammatory condition; and thus it is, that whilst

e central part of a mass of tissue, in which the inflammation has been ost intense, suffers complete death, and is carried away in the sup-rative process, the peripheral part, in which the violence of the inflam-ition has been less, becomes infiltrated with plastic matter poured out m the blood, and forms the solid and impermeable wall of the abscess. ee CHAP. XI. SECT. 3.)

194. Turning now to the Corpuscles of the Blood, we have to inquire to *their* special functions, and into the nature of their participation in e vital operations of the system at large. Here, also, we are obliged rely upon evidence of a far less satisfactory nature than could be sired; and at whatever conclusions we may arrive, we must hold them probable only, and as liable to be modified by further inquiry.—In the st place, upon looking to the chemical constitution of the Red cor-scles, we have seen that it possesses a remarkable correspondence with at of Muscle, in the proportion of the potash-salts which they contain; this respect differing in a very marked manner from the liquor san-inis. So, again, it exhibits a like correspondence with that of the Nerve-bstance, in the quantity of phosphorized fat which it includes (§ 142). gain, the peculiar colour which the vesicular nervous matter and the iscular substance of warm-blooded animals exhibit, although doubt-s attributable in part to the actual presence of red blood in these sues, yet partly depends upon a pigmentary matter in their own sub-ince, which seems closely to resemble hæmatin (§ 31). Thus, then, m the relative composition of the Red corpuscles and of the Muscular d Nervous tissues, there appears to be much reason for regarding the mer as destined to prepare or elaborate materials which are to be sub-vient to the *nutrition* of the latter. Again, we have seen that although difference in the colour of the red corpuscles of arterial and venous od, cannot now be considered (as it formerly was) to be an indication chemical change in their contents—effected, on the one hand, by the ency of carbonic acid, and, on the other, by that of oxygen,—yet there ll appears reason to regard these corpuscles as having more power of sorbing those gases, than is possessed by any other constituent of the od (§ 142). Hence we may look upon them as specially subservient the *vital activity* of the nervo-muscular apparatus; since it is one of most important conditions of that activity, that these tissues shall be pplied with duly oxygenated blood, and that the carbonic acid which is e of the products of their disintegration shall be conveyed away. And is view is in complete harmony with the fact, that the proportion of Red rpuscles in the blood bears a close relation to the amount of Respi-ory power (as shown in the quantity of carbonic acid set free, and in amount of heat generated) in different classes of Vertebrata; *both* ing greatest in Birds, nearly as great in Mammals, very low in most ptiles, and varying considerably among Fishes.* Again, we observe

* "Princ. of Phys., Gen. and Comp.," § 619. Among Invertebrated animals, as a general e, the degree of nervo-muscular energy that can be put forth, the quantity of carbonic acid duced in respiration, and the amount of heat generated in the body, are alike at a low ndard; and the fluid constituents of the blood, with the colourless corpuscles that float in would seem to convey oxygen to the tissues, and carbonic acid to the respiratory organs, h sufficient facility. In Insects, however, the case is different; their nervo-muscular ivity, capacity of respiration, and heat-producing power being all extraordinarily high.

that among Carnivorous Mammalia, the proportion of red corpuscles is considerably greater than it is among the Herbivorous tribes, whose nervo-muscular energy is (upon the whole) so greatly inferior; and it is in the condition of greatest animal vigour, in the Human system, that we find their amount the greatest, whilst the reduction of that vigour by chronic disease of any description, seems invariably attended with a more marked diminution in this constituent of the blood than in any other. And in those Anæmic states of the system, in which the proportion of red corpuscles is reduced to an extremely low point (§ 174), we invariably find that the animal powers are correspondingly depressed; the capacity for *sustained* exertion, either of the mental faculties, or of the motor apparatus, being almost destroyed, although both the nervous and muscular systems are very easily excited to feeble action.—However difficult it may seem to explain, on this view, the persistence of any degree of nervo-muscular power, in such cases as that already referred to, in which the Red corpuscles appeared to be entirely deficient (§ 176), the same difficulty attends *any* attempt to assign a use for them, which shall be in accordance with their well-marked importance as constituents of the Blood. And we may suppose that, in such cases, the Colourless corpuscles, although discharging the duty less perfectly, might to a certain extent perform it, as they seem to do among the Invertebrata.

195. The difficulty of precisely determining the functions of the Red corpuscles, is even surpassed by that of assigning the probable duty of the Colourless. The considerations already adduced appear to show, that the Colourless corpuscles are to be considered as cells of a lower grade than the Red; since they represent them among Invertebrated animals, and also in the incipient blood of Vertebrata; and also, because cells resembling the former (if not the very same) pass on to develope themselves into the latter (§ 155). Still we find that this final change does not occur among the Invertebrata; and it is obvious, therefore, that even in their colourless state, the corpuscles have a function to discharge in the vital economy. Little light has yet been thrown upon this subject by inquiry into the Chemical composition of the blood-corpuscles of the lower animals; and no means have yet been devised for obtaining the colourless corpuscles of the higher in a separate state, for the purpose of determining this. A minute sample of the blood-corpuscles of a Crab, however, examined by Prof. Graham, has been found by him to contain "a sensible quantity of iron, the proportion being perhaps as large as in red corpuscles." * Thus, then, we have evidence that the difference of hue between the two sets of Corpuscles, does not involve any considerable difference in the proportion of one of the most characteristic elements of the Red; and if it be admitted that they are both to be looked-upon as having the same origin, and as differing only in their stage of development, it is manifest that no other difference can fairly be expected to exist in their contents, than that which is marked by the formation of the colouring matter, as the final effort of their transforming power. This product, as we have seen (§ 142), constitutes but about *one-twentieth* of

Their want of red corpuscles would here seem to be compensated, so far as the respiratory process is concerned, by the introduction of air, through the tracheal apparatus, into the tissues themselves. ("Princ. of Phys., Gen. and Comp.," § 520.)

* "Philosophical Transactions," 1846, p. 105.

e whole contents of the Red corpuscles.—The following observation by r. Newport seems to indicate, that the corpuscles of the blood of sects (some of them in the condition of 'granule-cells,' others in that 'nucleated colourless cells,' § 147), have an important function to rform in the elaboration of nutrient material. The 'oat-shaped' rpuscles (the 'granule-cells' of Mr. Wharton Jones) are found, in the rva, to be most numerous at the period immediately preceding each ange of skin; at which time the blood is extremely coagulable, and idently possesses the greatest formative power. The smallest number e met with soon after the change of skin; when the nutrient matter of e blood has been exhausted in the production of new epidermic tissue. the Pupa state, the greatest number are found at about the third or urth day subsequent to the change; when preparations appear to be ost actively going on, for the development of the new parts that are to pear in the perfect Insect. After this, there is a gradual diminution; e plastic element being progressively withdrawn by the formative prosses; until, in the perfect Insect, very few remain. When the wings e being expanded, however, and are still soft, a few oat-shaped corscles circulate through their vessels; but as the wings become consoated, these corpuscles appear to be arrested and to break down in the rculating passages; supplying, as Mr. N. thinks, the nutrient material the completion of these structures, which subsequently undergo no ange.* The blood also contains nucleated cells, the proportion of iich seems to increase in the Imago state, whilst that of the 'granulels' diminishes.

196. That condition of the corpuscular element of the blood which is rmal in the Insect, must be considered as decidedly abnormal in the rtebrated animal, in which the circulating fluid goes on to a higher ase of development; and the excess of Colourless corpuscles in the ter seems always to be associated (save in the early part of life) with imperfect performance of their nutritive operations. Thus, according the observations of Mr. Paget, they are especially abundant in the ood of frogs that are young, sickly, or ill-fed; and whilst in the first of se cases, their large number seems to depend upon rapid increase, so it new red corpuscles may be generated in adaptation to quick growth, the two latter their accumulation seems rather to be attributable to a ardation of development through disease or defective nutriment, so it, although their production is not hindered, their normal metamorosis does not take place. So, as regards the human subject, Mr. Paget nfirms the statement of Mr. Wharton Jones and Prof. J. H. Bennett, it the increased proportion of Colourless corpuscles which has been garded by some observers (especially by Mr. Addison and Dr. C. J. B. illiams) as characteristic of inflammatory blood, and particularly of it which is drawn from an inflamed part, is far from being a constant enomenon; being most frequent when the subjects of the disease are rsons in weak health, or of the tuberculous diathesis, as has been rerked also by Nasse and Popp.† And Mr. Paget has furnished a remarkle confirmation of this view, in the observation, that the inflammatory udations produced in different individuals, by the application of the

* "Philosophical Magazine," May, 1845.

† 'Lectures on Inflammation,' in "Medical Gazette," 1850, vol. xlv. pp. 972, 973.

same stimulus on the same tissue (*e.g.* by the action of a blister on the skin) are found to present a predominance of the *fibrinous* or of the *corpuscular* element, according to the general condition of the patient. "The highest health is marked by an exudation of the most perfect and unmixed fibrin; the lowest, by the most abundant corpuscles, and by their nearest approach, even in their early state, to the characters of pus-cells. The degrees of deviation from general health are marked, either by increasing abundance of the corpuscles, their gradual predominance over the fibrin, and their gradual approach to the character of pus-cells, or else by the gradual deterioration of fibrin, which, from being tough, elastic, clear, uniform, and of filamentous appearance or filamentous structure, becomes less and less filamentous, softer, more paste-like, turbid, nebulous, dotted, and mingled with minute oil-globules." "After some practice," adds Mr. Paget, "one might form a fair opinion of the degree in which a patient was cachectic, and of the degree in which an inflammation in him would tend to the adhesive or to the suppurative character, by the microscopic character of these exudations."* —From such evidence we seem forced to the conclusion, that, whether or not the Colourless corpuscles are to be regarded in any other light than as blood-cells not yet fully developed, their multiplication is *not* (as has been maintained) the source of increase in the fibrinous constituent of the liquor sanguinis.† Whether the arrest of development of these corpuscles, in the abnormal conditions just referred to, is to be attributed to an original want of capacity in their germs, or to some agency which

* Op. cit. p. 1015.

† The Author is not ashamed thus to record his withdrawal of an opinion which he formerly held, and for which he even strenuously contended. His belief was founded in great part upon the assertions of Mr. Addison ("Experimental Researches on the Process of Nutrition," First and Second Series), and of Dr. C. J. B. Williams ("Principles of Medicine," second edit. pp. 258—266), as to the uniform concurrence of an increased production of Colourless corpuscles, with the augmentation of Fibrin usually regarded as characteristic of the inflammatory state; and this having been disproved by the researches of Mr. Paget and other trustworthy observers, he abandons the idea as one no longer tenable. He has the satisfaction of finding, however, that Mr. Wharton Jones has, on his side, given up the doctrine that the *Red* corpuscles dissolve into the fibrin of the blood; against which the Author had argued, whilst endeavouring to substantiate his own. Mr. Wharton Jones appears to be now satisfied, that "the inverse proportion in the quantity of red corpuscles and fibrin, though frequent, has not always been found to obtain; and when found, the diminution in the red corpuscles has not been in any regular relation to the increase in the quantity of fibrin; moreover, the quantity of red corpuscles which disappear, is quite disproportionate to the comparatively small addition to the quantity of fibrin." (See his Prize Essay 'On the state of the Blood and the Bloodvessels in Inflammation,' in the "Guy's Hospital Reports" for 1850, p. 68.) Still, the above observations of Mr. Paget and others seem to indicate some relation of *reciprocity* between the Colourless corpuscles and the fibrin; while those of Mr. Newport (§ 195) favour the belief, that these corpuscles may melt down into a substance adapted for the nutrition of the tissues. An observation of Mr. Addison's too, which the Author has himself confirmed, appears to sanction the idea (although by no means proves) that the colourless corpuscles emit a fibrillating material in bursting. (See his "Experimental Researches," second series, p. 4.) The Author cannot help still suspecting, therefore, that the Colourless corpuscles are not to be regarded *merely* as red blood-cells in their earlier phase of development; but that they have some special connection with the elaboration of the plastic constituents of the blood. Warned, however, by previous experience, of the danger of building conclusions upon observations of a limited and imperfect character, he refrains at present from offering any hypothesis as to the nature of that relation,—merely suggesting that it is far from certain that all the bodies which pass under the designation of 'white' or 'colourless corpuscles' are of the same kind, as is shown by the fact, that cells are formed in exudations, which cannot be distinguished from the colourless cells of the

ıbsequently depresses their vital power, or to the want of some material ·hich they require for the purpose, can scarcely at present be decided; ud it may be doubted whether any one of these determining causes is ı action in every case, or whether each of them may not occasionally perate, either singly or in combination.

197. Turning now to those constituents of the Blood which show no ıdications of possessing vitality, we have first to speak of its *Albumen.* 'he relations which this substance bears to the living body are of the ıost important and fundamental character; since, as already shown § 20), it is the original *pabulum* at the expense of which all the solid ssues are generated, whilst it also affords the material for the production f the fibrin, the globulin, and the hæmatin of the blood itself. It ppears, however, to be itself entirely destitute of formative capacity; for ı no exudation which is purely serous, do we ever trace the slightest ıdication of organization; and its conversion into the various kinds of ssue, therefore, must be entirely due to their own power of appropriating nd transforming it.* The great function of the Albumen of the blood, ıen, is to supply the material for these various transformations; and e accordingly find that whatever other changes the fluid may undergo, ·hether it loses its fibrin or its red corpuscles, or both, albumen is still resent in abundance. Its ultimate source is to be found in the food; ut the serous liquid which percolates the tissues of the body may be ɔoked upon as a reserve-store to be drawn upon in case of need, furnish- ıg albumen to the blood when it might otherwise be deficient; and thus erhaps it is, that abstinence or repeated losses of blood do not produce he degree of depression in the proportion of albumen, which might be xpected from the very marked reduction which they effect in that of the orpuscles.† When an excess of Albuminous matter is ingested as food, ıe injurious effects which might follow the too great augmentation of his constituent of the Blood, appear to be averted by the readiness with ·hich it undergoes *retrograde* as well as *progressive* metamorphoses; for, f not speedily subjected to the latter change, it appears to be affected by ecomposing agencies, and to be eliminated from the system by the

·lood, and which yet can scarcely be supposed to be rudimental red-corpuscles; and that if ɔme of the 'colourless corpuscles' of the blood be looked upon as instrumental in elaborating :s plastic components, whilst others are on the march of development into red corpuscles, ; seems very probable that the same depressing influence which checks the latter process hould also interfere with the former, and that thus an accumulation of colourless corpuscles in achectic subjects may coincide with a diminution in the red, and at the same time with an nperfect elaboration of the fibrin of their blood.

* Those who maintain that Fibrin is the only organizable constituent of the blood, and hat it is the immediate source of the nutrition of the tissues generally, consider that Albu- ıen cannot be appropriated by the tissues without first passing through the Condition of brin. This doctrine, formerly contended for by the Author, he now abandons as inconsistent ·ith much that we know of the history of fibrin and of its destination in the body (§ 192); nd he would rest upon the simple fact, that the first development of the embryonic mass, by he multiplication of its component cells, takes place in a fluid in which nothing analogous to brin can be discovered, as showing that cells are able to draw their support directly from an *lbuminous* pabulum; whilst it is only when the gelatinous tissues begin to be formed in the mbryo, that we find its blood to become spontaneously coagulable.

† It is to be remembered, however, that the whole mass of the blood (liquid as well as olid) is probably reduced under these circumstances; it having been found by the experi- ıents of Chossat ("Recherches Expérimentales sur l'Inanition"), that when animals were illed by starvation, the blood lost no less than 75 per cent of its weight, whilst the average ›ss of the whole body was 40 per cent.

excretory apparatus, under the form of urinary and biliary matter. (See CHAP. XII.) As already pointed out, however, although Albumen seems to furnish certain constituents of secretions which are applied to special purposes within the body, yet its passage *as such* into the excretions must be looked upon as quite abnormal, and as (so to speak) a mere waste of nutrient material (§ 21).

198. The Fatty matters of the Blood are obviously destined to furnish the contents of the adipose and nervous vesicles; whilst their presence seems also to be required in the early stages of the production of cells generally (§ 42). One of the principal sources of their expenditure, however, is that combustive process by which the heat of the body is maintained; and the amount deposited in the tissues as fat, may be looked upon as the surplus of the quantity ingested, that is not thus consumed. The quantity of fatty matter in the blood is liable to sudden augmentation, from the introduction of a large quantity furnished at once by the alimentary material; and this excess will continue until the surplus has been eliminated, either by the combustive, the nutritive, or the excretory operations. These last do not ordinarily remove the saponifiable fats from the body; for although the mammary secretion in the female draws off from her blood a large quantity of fatty matter, this is destined not for its purification, but for the nutrition of her offspring; and cholesterin appears to be the only fatty substance which is normally excreted for the purpose of removing it from the body. Fatty matters are often detectable in small quantities in the healthy fæces, where, however, their presence may be attributed to the non-absorption of a portion of those which the food had included; and this want of absorption seems especially to occur in cases in which the action of the Pancreas is disturbed by disease of that organ.* But they are sometimes discharged in such large quantities, that it is scarcely possible thus to account for their presence; and it would seem that they must have been poured into the alimentary canal, either by the liver or by some other excreting organ, which must have drawn them off from the blood. It does not seem an improbable surmise, that in such cases there may be an extraordinary tendency to the metamorphosis of albuminous and other azotized matters (whether furnished by the tissues or by the food) into fat (§ 40); and that the excretion of this substance does in effect tend to keep down their proportion in the blood. Their occasional extraordinary accumulation in the circulating fluid (§ 176) tends to confirm this view; for it appears scarcely possible that such an enormous proportion of fat could have been derived from the food, either in the condition of fat, or in that of a saccharine compound capable of being converted into it.

199. All the other Organic compounds which have been distinctly recognized in the blood, or of whose presence in the circulating current we have inferential evidence,—sugar, lactic acid, urea, uric acid, hippuric acid, creatine, creatinine, the volatile fatty acids, and the odorous substances,—are to be considered, not as in any way subservient to those constructive changes in which Nutrition properly consists, but as products of the retrograde metamorphosis, either of the alimentary materials, or of the tissues themselves; and as on their way to be eliminated

* See Mr. A. Clark, in the "Lancet" for Aug. 16, 1851.

from the blood, either by the respiratory organs, or by some other part of the excretory apparatus. And the more perfect the balance between the action of this apparatus, and the operations whereby these compounds are generated, the less will be the proportion in which they present themselves in the blood, and the greater will be the difficulty in detecting them there.

200. The uses of the various *Inorganic* compounds, which, as being uniformly present in the Blood, must be considered among its integral constituents, are not as yet by any means positively known; yet great advances have been recently made towards this knowledge; and it may be pretty certainly affirmed, that the presence of some of them has reference to the peculiar functions and conditions of the blood itself, whilst others are chiefly destined for appropriation by the tissues to whose growth it ministers. Thus the *phosphate and carbonate of soda* would seem to have it for their chief purpose, to maintain the alkalinity of the blood, on which its other properties so much depend (§ 83), and to increase the absorptive power of the serum for gases (§ 84); the *salts of potash*, on the other hand, appear to be specially required for the nutrition of muscular tissue (§ 85); whilst the presence of *chloride of sodium* is needed alike for the conservation of the organic elements of the blood in their normal condition, and for the supply of the salt which is required as a component, not only of the solid tissues, but also of all the secreted fluids (§ 82). The presence of the Earthy salts, on the other hand, would seem to have reference almost exclusively to the composition of the tissues, into which some of them enter very largely. The *phosphate of lime* in particular must be regarded almost in the light of a histogenetic substance, so constantly does it seem to be present in newly-forming tissues; whilst it is also in great demand as the principal consolidating material of bone and tooth (§ 86). Whether the *carbonate of lime*, the *phosphate of magnesia*, the *fluoride of calcium*, and the *silica* of the blood, are of any other use in it than to supply consolidating materials for the tissues, there is at present no evidence whatever. *Iron*, like the alkaline salts, is an essential constituent of the blood itself, forming a very large per-centage of the hæmatin of its red corpuscles; and it is supplied by the blood to various tissues, especially the muscles and the hair, of which also it may be considered an essential component (§ 87).—The normal proportions of all these substances appear to be chiefly maintained by means of the excretory apparatus, which filters-off (so to speak) any surplus; it being through the urinary organs that they are chiefly eliminated. And it is by them, too, that the normal proportion of *Water* in the blood is chiefly maintained; the Malpighian apparatus of the kidneys apparently acting as a kind of safety-valve, through which any surplus that remains after the cutaneous, pulmonary, and intestinal exhalants have performed their appropriate duties, is allowed to make its escape.

201. It is not alone by the proper Excretory apparatus, however, that the fitness of the Blood for circulation through the body is maintained. Every tissue draws from the circulating fluid some particular material, or combination of materials, which constitutes its own special *pabulum;* and as the 'pabulum' of each tissue is different, it follows that the normal composition of the blood can only be preserved, without waste of substance, by the existence of such a balance between the appropriative action of the

several parts, as shall cause a certain equivalent of blood to supply, without deficiency or surplus, the materials which they collectively require. Such a balance is, in fact, ordinarily preserved; and its maintenance is one of the most marvellous of those exemplifications of Design, which the vital economy of the body presents in no less a degree than its organized structure; an exemplification, however, which becomes yet more marvellous, when it is shown that not only every kind of tissue, but every spot of every organ, has its own special 'pabulum;' drawing something from the blood, which is different from that appropriated by every other part of the body, save by the corresponding spot on the opposite side. This position seems fully established by the researches of Dr. W. Budd and of Mr. Paget on 'Symmetrical Diseases'* the phenomena of which are full of interest, as illustrating the ordinary operations of Nutrition. Excluding the cases of congenital symmetrical defects, and a few which seem to depend on morbid influence of the nervous system, it may be stated as a general fact, that all symmetrical diseases depend on the presence of some morbid material in the blood, which usually enters into combination with the tissue that is diseased, or with the organized product of the morbid process. Such a substance fastens upon certain spots or islands on one side of the body, leaving the surrounding parts unaffected; and precisely similar spots or islands are affected in like manner on the other side. The conclusion seems unavoidable, that, however closely one portion of skin or bone may seem to resemble another, the only parts that are *exactly* alike are those which repeat each other symmetrically on the opposite sides of the body; for, although no power of artificial chemistry may determine the difference, the chemistry of the living body makes it evident, the morbid material testing-out the parts for which it has the greatest affinity, uniting with these alone, and passing by the rest. It is continually observable, moreover (as Mr. Paget has remarked), that a poison of the same kind will attack corresponding spots, not merely on the two sides of a single individual, but also on the two sides of any others who may have imbibed it into their systems. Thus the syphilitic poison has its 'seats of election' when it begins to attack the bones, fixing upon certain parts of the tibiæ and of the skull with great uniformity; and in the Hunterian Museum are the pelves of two lions, on both of which new osseous deposit has taken place (as the product of some disease resembling rheumatism in man) in a most complex and irregular pattern, this being so similar in the two, that almost every spot and line of the one is represented in the other, with an exactness only inferior to the symmetrical correspondence between the two sides of each.† It has been further pointed out by Dr. W. Budd, as indicated by the phenomena of these diseases, that next to the parts which are symmetrically placed, none are so nearly identical in composition as those which are analogous, such as the corresponding parts of the superior and inferior extremities.—All these facts tend to demonstrate the perfect and most minute exactness of the adaptation which must exist in the state of health between the blood and all the tissues, as well as the almost inconceivable minuteness of the departure from this adaptation which may become a

* See their original Essays on this subject in the "Med.-Chir. Trans." vol. xxv.

† See Mr. Paget's 'Lectures on Nutrition, &c.' in the "Medical Gazette" for 1847; Lect. I.

ource of disease; and it is a sure indication of the safety with which we nay found such inferences upon them, that the phenomena of symmetrial disease are most distinct, when the disordered action is most conformble, as to its character and its rate, to the normal nutrition of the tructure; it being in diseases which (though dependent upon a poison a the blood) are of an inflammatory or other violent nature, that the ymmetry of the morbid change is least obvious.

202. Thus, then, we are led to the conclusion, that, as Treviranus hrased it, "each single part of the body, in respect of its nutrition, ands to the whole body in the relation of an excreted substance;" or, in ther words, each part of the body, by taking from the blood the peculiar ıbstances which it needs for its own nutrition, does thereby act as an cretory organ, inasmuch as it removes from the blood that which, if tained in it, would be injurious to the nutrition of the body generally. hus, the phosphates which are deposited in our bones, are as effectually creted from the blood, and as completely prevented from acting injuously on other tissues, as those which are discharged with the urine.—he applications of this doctrine have been greatly extended by Mr. aget, who has given the following among other examples of its bearing pon the general relations between the blood and the tissues. The hairy overing may be considered to serve, over and above its local purposes, r the removal of certain components of the blood, which would be injuous to its constitution if they remained and accumulated in it; and cordingly we do not find that its development is delayed, until near the eriod when its protection will be required; for a complete coat (the *nugo* of the human fœtus) is formed in the fœtus of mammals generally, hilst they are still within the uterus, removed from all those conditions gainst which hair is a defence; and this coat is shed very soon after rth, being replaced by another of wholly different colour, the growth of hich had begun within the uterus. The same principle leads to the oprehension of the true import of the hair which exists in a kind of ıdimental state on the general surface of our bodies; and thence to the al meaning of the existence of other organs which permanently remain a rudimental state, such as the mammary glands of the male. For, as r. Paget justly remarks (loc. cit.) "these rudimental organs certainly do ot serve, in a lower degree, the same purposes as are served by the omologous parts which are completely developed in other species, or in e other sex. To say they are useless, is contrary to all we know of the solute perfection and all-pervading purpose of creation; to say they ist merely for the sake of conformity to a general type of structure, is rely unphilosophical, for the law of unity of organic types is, in larger stances, not observed, except when its observance contributes to the vantage of the individual. No: all these rudimental organs must, as ey grow, be as excretions serving a definite purpose in the economy, by noving their appropriate materials from the blood, thus leaving it fitter the nutrition of other parts, or adjusting the balance which might herwise be disturbed by the formation of some other part. Thus they nister to the self-interest of the individual; while, as if for the sake of nder, beauty, and perfect order, they are conformed with the great law unity of organic types, and concur with the universal plan observed in construction of organic beings."

203. But further, it has been already pointed out (§ 120) that the presence of a certain substance in the Blood, appears to determine the formation of the tissue of which that substance is the appropriate pabulum. And thus, as the abstraction of the material required for each part leaves the blood in a state fitted for the nutrition of other parts, it seems to follow, as Mr. Paget has further remarked (Op. cit. Lect. II.), that such a mutual dependence exists amongst the several parts and organs of the body, as causes the evolution of one to supply the conditions requisite for the production of another; and hence, that the order in which the several organs of the body appear in the course of development, while it is conformable to the law of imitation of the parent, and to the law of progressive ascent towards the higher grade of being, is yet the immediate result of changes effected in the condition of the blood by the antecedent operations. And this view is confirmed by many circumstances which indicate, that certain organs really do stand in such a *complemental* relation to one another as it implies; a large class of facts of this order being supplied by the history of the evolution of the generative apparatus, and by that of the concurrent changes in other organs (especially the tegumentary) which are found to be dependent upon it, although there is no direct functional relation between them. Thus, the growth of the beard in man at the period of puberty, is but a type of a much more important change which takes place in many animals with every recurrence of the period of generative activity. This is most obvious in birds, whose plumage, at the commencement of the breeding season, becomes (especially in the male) more highly coloured, besides being augmented by the growth of new feathers; but when the sexual organs pass into their state of periodic atrophy, the plumage at once begins to assume a paler and more sombre hue, and many of the feathers are usually cast, their nutrition being no longer kept up. It is a matter of common observation, that the deficiency of hair on the face (where this is not, as among the Asiatics, a character of race) is usually concurrent with a low amount of generative power in the male, and may be considered as indicative of it; whilst, on the other hand, the presence of hair on the upper lip and chin of the female is indicative of a tendency in the general organization and mental character towards the attributes of the male, and of a deficiency in those which are typical of the female. If, moreover, the development of the male organs be prevented, the evolution of the beard does not take place; whilst the cessation or the absence of activity in the female organs is often attended by a strong growth of hair on the face, as well as by other changes that may be attributed to the presence of some special nutritive material in the blood, for which there is no longer any other demand. This, again, shows itself yet more strongly in Birds; among which (as Hunter long since pointed out*) it is no uncommon occurrence for the female, after ceasing to lay, to assume the plumage of the male, and even to acquire other characteristic parts, as the spurs in the fowl tribe. Moreover, it has been ascertained by the experiments of Sir Philip Egerton, that if a buck be castrated while his antlers are growing and still covered with the 'velvet,' their growth is checked, they remain as if trun-

* 'Account of an Extraordinary Pheasant,' in "Hunter's Works," Palmer's edit. vol. IV. p. 44.

cated, and irregular nodules of bone project from their surfaces; whilst, if the castration be performed when the antlers are full grown, these are shed nearly as usual at the end of the season, but in the next season are only replaced by a kind of low conical stumps.

204. That these and similar changes in the development of organs are immediately determined by the condition of the circulating fluid, that is, by the presence or absence of the appropriate 'pabulum' for the parts in question, would further seem likely from the fact, that they may be artificially induced by circumstances which directly affect the condition of the blood. This has been shown by Mr. Yarrell,* in regard to the assumption of the male plumage by the female; and a still more remarkable and satisfactory proof is furnished by the conversion of the 'worker' larva of the Bee into a perfect 'queen,' solely through a change of diet.† And thus we are led to feel that Mr. Paget's doctrine of 'complementary nutrition,' whilst it has the advantage of grouping together a great number of phenomena which would otherwise seem to be unrelated to each other, really possesses a definite foundation in well-known and universally-admitted facts, which can scarcely be viewed in any other light. To use his own expression of it, "the development of each organ or system, co-operating with the self-development of the blood, prepares it for the formation of some other organ or system, till, by the successive changes thus produced, and by its own development and increase, the blood is fitted for the maintenance and nutrition of the completed organism." And further, "where two or more organs are manifestly connected in nutrition, and not connected in the exercise of any external office, their connection is because one is partly formed of materials left in the blood by the formation of the other; so that each, at the same time that it discharges its own proper and external office, maintains the blood in the condition most favourable to the development of the other."

205. Thus, then, the precise condition of the Blood at any one time is dependent upon a vast variety of antecedent circumstances, and can scarcely be the same at any two periods of life. Yet we find that, taken as a whole, it exhibits such a remarkable constancy in its leading features, that we can scarcely fail to recognize in it some such capacity for self-development and maintenance, as that which the solid tissues are admitted to possess. And this idea may be thought less strange, when it is borne in mind that the first blood is formed by the liquefaction of the primordial cells of the embryo, and that, notwithstanding the continual change in its components, it still retains its identity through life, in no less a degree than a limb or an eye, the material changes in which, though less rapid, are not less complete. Looking, again, to the undoubted vitality of the corpuscles, and to the strong ground for regarding the Fibrin also as an instrument of vital force, we cannot but perceive that the Life of the Blood is as legitimate a phrase, and ought to carry as much meaning in it, as the Life of a Muscle. And as the one has a period of growth, development, and decline, so must the other.—This view is borne out, not merely by those palpable differences in the composition of the blood at different ages, which are detectable by our rude methods of examination;

* "Philosophical Transactions," 1827.

† "Princ. of Phys., Gen. and Comp.," § 60.

but also by those alterations in the tendency to particular constitutional diseases, which at the same time mark the advance of life, and indicate minute and otherwise inappreciable alterations in the circulating fluid. For it is obvious that since the poison of small-pox, for example, less readily produces its characteristic 'zymosis' in the blood of the adult than it does in that of the child, the latter must differ from the former, either in composition or in vital endowments; and that since the tendency to 'fatty degeneration' of the tissues generally shows itself in a far stronger degree in the aged person than in the adult, this is likely to be in part owing to the condition of the blood, in which, according to the observations of Becquerel and Rodier, there is a decided and progressive increase of cholesterin after the age of 40 or 50 years.

206. Thus, then, we seem justified in the belief that the Blood, like the solid tissues, has a formative power of its own, which it exerts in the appropriation of the new material supplied to it from the food; and that, like all the other parts descended from the component cells of the germinal mass, it goes through a succession of phases, which are partly the cause, and partly the effect, of developmental changes in the organism generally. So long as the operations of Nutrition are normally carried on, the materials that are withdrawn by the several parts of the body may be considered so far to balance one another, that no *waste* is incurred from this source; and if the amount of new matter introduced be merely the equivalent of that which is required for the nutritive operations, nothing else will occasion a demand for elimination, save the products of the disintegration of the tissues, which are received back into the blood for this purpose. But it must be very rarely that this balance is precisely maintained for any length of time, since a multitude of circumstances are continually occurring to derange it; the most frequent, perhaps, being the ingestion of certain nutritive materials in greater quantity than they are required. And we then find that the organs take upon themselves a supplemental action for the removal of the superfluity; the kidneys being especially charged with this duty in the case of azotized and saline matters, and the liver and lungs in regard to hydrocarbonaceous substances. It is obviously of importance, however, to overtask these organs as little as possible; and when such superfluity is becoming a source of disease, the obvious treatment is rather to prevent it from being thrown upon them for separation, by diminishing the supply of aliment generally, or of some particular article of diet, than to excite them to increased activity by stimulating medicines.

207. The self-maintaining power of the Blood is yet more shown in the phenomena of Disease; and especially in its spontaneous recovery of its normal condition, after the most serious perversions; as we see more particularly in febrile diseases of definite type (such, for example, as the Exanthemata, Typhoid, Typhus, &c.), of whose origin in the introduction of specific poisons into the blood, there is no reasonable ground for doubt. In studying the mode in which these and other 'morbid poisons' act upon the blood, and through it upon the system at large, we may derive important assistance from a previous inquiry into the history of the action of those poisonous agents, which, from their being more readily traceable by chemical analysis, can be more satisfactorily made out. Such an inquiry has a most important bearing, also, on the *modus operandi* of

medicines.—The operation of medicinal or poisonous substances for the most part depends upon the power which they possess, when introduced into the current of the circulation, of effecting some determinate change in the *chemical* and thereby in the *vital* condition, either of the components of the blood, or of some one or more of the tissues which it nourishes; and their determination to some special part or organ must be attributed to the same kind of elective affinity, as that by which the normal constituents of the blood are so determined (§ 201). Now of nearly all these substances it may be said, that the system, if left to itself, tends to free itself from them, provided *time* is allowed for it to do so; and that, when death results from their introduction into it, the fatal result is to be attributed to the fact, that the disorganization of structure and disturbance of function are too rapid and violent, to allow the eliminating processes to be set in efficient operation. When smaller doses are taken, their effects are evanescent, unless the abnormal action to which they may have given rise is of a kind to perpetuate itself;* and their cessation is obviously attributable to the removal of the agent from the system, whereby the continuance of its deleterious agency is prevented. Of this removal, we have of course the most satisfactory evidence in the case of those substances, which can be detected by ordinary chemical tests in the excretions. Thus, as a general rule, alkaline, and earthy salts that have been absorbed into the blood, are discharged in the urinary secretion, which is itself increased in amount, showing that their action is specially determined towards the kidneys. So, again, arsenic, tartarized antimony, and a variety of other metallic substances, have also been detected in the urine, for some days after they have been ingested; showing that their elimination is a work of time. On the other hand, the salts of copper appear rather to be removed from the blood by the liver, and also by the bronchial secretion. And lead, which passes off but little by the ordinary excretions, is withdrawn from the circulation by various tissues and organs, but particularly by certain parts of the muscular apparatus, with the substance of which it becomes incorporated, producing a most injurious influence upon its vital endowments.†—The only exception to the general rule above stated, seems to be in the case of those medicines, which have what is called a 'cumulative' tendency; this tendency being, in fact, simply the result of their want of stimulating influence upon the excretory organs, whose functional activity is rather impeded than promoted by them. This is pre-eminently the case in regard to lead, which is probably the most cumulative poison with which we are acquainted; its continual introduction in doses of even extreme minuteness being capable, if sufficiently prolonged, of causing the most serious disturbance in almost every function in the economy. Even here, it is rather in the tissues, than in the blood, that it accumulates,—as is indicated by a variety of facts, but more especially by the difficulty with which it is eliminated from the system by means that would be probably effectual in removing it from the circulating current;—and thus we see that, in default of other

* Such a perpetuation is seen in the chronic inflammation, thickening, and contraction, of the œsophageal walls, consequent upon the deglutition of strong acids and caustic alkalies.

† This has been shown by the analyses of M. Devergie (see the "Traité des Maladies de Plomb," of M. Tanquerel, tom. ii. pp. 401–6), and of Prof. Miller (see Dr. W. Budd's essay on 'The Symmetry of Disease,' in the "Medico-Chirurgical Transactions," vol. xxv.

provision for maintaining the purity of the blood, the whole body (so to speak) acts as an excretory apparatus, and draws into itself the noxious substance.

208. There is a large number of cases, moreover, in which, although the poisonous or medicinal substances cannot be traced in the excretions by chemical tests, their effects, when moderate doses have been taken, pass off so completely, that there can be no doubt of their not being any longer present, as such, in the system; and the substances of this class are of a nature and composition which render them peculiarly susceptible of change, when subjected to the influences which they will encounter in the living body, and more especially when exposed in a state of very fine division to the agency of oxygen. A familiar exemplification of this mode of elimination of poisons is furnished by the transient duration of the effects of a dose of alcohol, even when this is large enough to produce insensibility; recovery from them being merely a question of time, provided that the state of torpor, produced by the action of this poison on the centre of the respiratory movements, be not so profound as to occasion Asphyxia, or that death do not result (as sometimes happens when the poison is taken in a state of concentration) from the immediate *shock* to the nervous system. Now the quantity of alcohol which passes off by the ordinary excretions is extremely slight; in fact, this substance can seldom be detected in them. But there can be no reasonable doubt that the elimination of the alcohol is due to its oxidation whilst passing through the circulating system, so that it is excreted by the lungs in the form of carbonic acid and water; and if confirmation of this view were needed, it is afforded by the tolerance of large doses of alcohol, which is shown when it is subjected with peculiar rapidity to the combustive operation, as during continued exposure to severe cold or prolonged muscular exertion, or in the exhaustion of wasting diseases when no other combustive material remains in the body. The same explanation is obviously applicable to the parallel phenomena, which present themselves in the action of opium, strychnia, prussic acid, &c. With all these, also, the question of life or death is one of time; for if the fatal result do not speedily follow the absorption of the poison into the blood, the patient gradually recovers from its effects; and the most effectual treatment consists in the artificial maintenance of the respiratory movements, which the influence of these poisons upon the nervous centres might otherwise suspend. These poisons cannot be detected in the circulating fluid by their sensible or chemical characters, if a short interval has elapsed subsequently to their absorption; thus it has been found by Dr. Lonsdale that the odour of prussic acid cannot be perceived in the blood or in the cavities, when life had been prolonged beyond 15 minutes, although, when death took place within a shorter time, the poison might be detected in the body by its odour alone for eight or nine days afterwards; and the presence of morphia ceases to be recognizable by the ordinary chemical tests, within a short time after it has been taken into the circulating current.—Even with regard to certain poisons of this unstable class, however, there is evidence that they pass into the urine and are thus eliminated, without undergoing any change that impairs their physiological action; this evidence being afforded by the effects of the re-ingestion of the urine, either by the individuals themselves, or by others.

A very curious example of this kind is afforded by the intoxicating fungus, *Amanita muscaria,* which is used by some of the inhabitants of the north-eastern parts of Asia in the same manner as alcoholic liquors by other nations. Its effects, like those of other excitants, have a limited duration; for a man who is intoxicated by it one day, 'sleeps himself sober' by the next. His restoration is due, however, not to his repose, but to the elimination of the poison which takes place during the interval; for if he drink a cup of his urine the next morning, he is yet more powerfully intoxicated than he was the preceding day; and the fluid has the same effect upon any other individual, into whose urine the active principle then passes; so that, according to the testimony of travellers, the intoxicating agent may be transmitted in this manner through five or six persons, a small stock at the commencement thus serving to maintain a week's debauch. Results of the same order have been obtained by Dr. Letheby in regard to opium, belladonna, hemlock, aconite, &c.; the passage of these substances into the urine being proved by the induction of their characteristic effects, when that fluid was administered to other animals. It is probable that, as in the case of lactic acid (§ 49), the appearance of these substances in the urine is due to their presence in the blood in such quantity, that the oxidizing process does not promote their elimination through the lungs with sufficient rapidity.

209. Between the substances which admittedly rank as *poisons,* and those which are reckoned as *materies morborum,* no definite line of demarcation can be drawn; and the train of symptoms produced by the operation of the former, is really as much *a disease* as that which results from the presence of the latter. The connection is, in fact, established, by those 'animal poisons' which are the result of decomposition either within or without the body; such as that of the 'pustule maligne,' or of the flesh of animals suffering under disease, on the one hand, or the 'cheese-poison,' 'sausage-poison,' &c. on the other.—It may be admitted that our belief in a specific material cause for a great part of the effects set down to the action of 'morbid poisons,' is merely inferential; and there are many persons, to whom their exhibition in a tangible form seems to afford the only convincing evidence of their existence. But it must be remembered that the evidence of chemistry itself is often purely inferential; for we recognize the presence of a chemical substance, not merely by obtaining it in a separate form, but by witnessing the reactions which it displays with various tests; and there is one substance, fluorine, which has never yet been isolated, and of whose existence, however, no chemist would hint a doubt. Now it is the human body which forms the appropriate testing-apparatus of 'morbid poisons;' and even if we could always obtain them in a separate state, and could subject them to chemical analysis, we should know much less of their most important properties, than that which we can ascertain by observation of their actions in the system; this alone affording the means of judging of their *dynamical* character, which is of far more importance than a knowledge of their chemical composition. In the case of those poisons which are capable of being introduced by inoculation, we have, indeed, the required proof of their material existence; and this proof is capable of being extended by a safe analogy to infectious diseases generally. For, if small-pox can be com-

municated by the inhalation of an atmosphere tainted with the exhalations of a person already affected with it, as well as by the introduction of the fluid of the cutaneous pustule into the blood of another, it can scarcely admit of a question, that the same poisonous agent is transmitted in both cases, although through different media, and that it has as real an existence in the transferred air, as in the transferred pus. Diseases, then, which are capable of being transmitted in both these methods, form the connecting link between those resulting from ordinary toxic agents, and those which must be assumed to depend upon a subtle poison, of which the air alone is the vehicle,—such, for example, as malarious fevers; this assumption being required by all the rules of logic, as the only one which will account for the phenomena to be explained, and therefore possessing a claim to be accounted an almost certain truth. There is a strongly marked difference, however, between the *modus operandi* of the toxic agents whose action has been previously examined, and that of the morbid poisons we are now considering; for whilst the former possess a certain definite action, the intensity of which (*cæteris paribus*) is proportionate to the quantity that is in operation, and which is usually determined, in virtue of the 'elective affinity' already spoken of, to some particular organ or tissue,—the latter act primarily upon the blood, influencing the system at large through the changes which they produce in its constitution, and their potency depends rather upon the susceptibility of the blood to their peculiar influence, than upon the quantity of the poison that may be introduced into it.

210. Of the existence of such susceptibility, as a 'predisposing cause' of *Zymotic* * disease, there cannot be the slightest doubt. In the case of the Exanthemata and Hooping-cough, we see that it is congenital, and is usually removed by the occurrence of one attack of the disease (although this is not a uniform protection); but the liability even to these varies greatly in different individuals, and at different times in the same individual. And with regard to other zymotic diseases, the liability to which is not thus limited, all extended observation concurs in showing that it is augmented by anything which tends to depress the vital powers of the system, and more particularly by any cause which obstructs the due purification of the blood, by the elimination of the products of decomposition. Thus, it will be shown hereafter (CHAP. X.), that no antecedent condition has been found so efficacious in augmenting the fatality of Cholera, as *overcrowding;* which compels those who are subjected to it, to be constantly breathing an atmosphere not only charged with carbonic acid, but laden with putrescent emanations; and which thus favours the accumulation of decomposing matter in the blood, which serves as the most appropriate soil for the seeds of the disease. And what is true of Cholera has been found to be true of Zymotic diseases in general; the very same fermentible matter in the blood serving for the development of almost any kind of zymotic poison that may be received into the system, whether from the atmosphere, or from the bodies of those who have already been subjects of the disease.—Now that what has been here spoken of as

* The term *zymotic* is a very convenient designation, which has of late gained general currency, for that class of diseases whose phenomena may be attributed to the operation of a morbid poison of the nature described above; this operation bearing a strong analogy to that of 'ferments.'

'fermentible matter' is not a mere hypothetical entity, but has a real material existence, appears from this consideration; that in all those conditions of the system in which we know that decomposition is going on to an unusual extent, and in which there is a marked tendency to putrescence in the excreted matters, we witness such a peculiar liability to zymotic diseases, as clearly indicates that the state of the blood is peculiarly favourable to the action of the zymotic poison. This is pre-eminently the case in the puerperal state, in which the tissue of the uterus is undergoing rapid disintegration, its vital force having been expended (§ 110); for there is now abundant evidence, that the contact of decomposing matters which would be innocuous at other times, is capable of so acting upon the blood of the parturient female, as to induce that most fatal *zymosis* which is known as 'puerperal fever.'* And her peculiar liability is in no respect more manifest than in this; that the poison by which she is affected may have lain dormant for weeks or months, for want of an appropriate nidus, and will yet exhibit its full potency on the very first case in which opportunity may be given for its introduction into the system of a puerperal patient.† The same kind of liability is displayed in the subjects of severe injuries, among whom, also, there is not only a depression of the vital powers, but also a special source of decomposing matter in the system; for there is evidence that 'surgical fever' may be induced in them by the introduction of a zymotic poison derived from a variety of external sources (amongst others, from patients affected with puerperal fever), such as would have no effect upon a healthy subject; and, moreover, that overcrowding in hospitals has a special tendency to increase this liability.‡ So, again, an excess of muscular exertion, producing an unusual 'waste' of tissue, especially when the elimination of the products of this waste is interfered with by imperfect respiration, is well known to engender a peculiar liability to zymotic disease; and this, too, finds its explanation in the same principle.§ — Thus, then, we may affirm with strong confidence, that the liability to zymotic disease depends upon the previous condition of the blood; and more especially on the presence of fermentible matters resulting from the ordinary processes of disintegration, which, in the state of perfect health, are eliminated as fast as they are formed, but of which

* For a most marked and convincing example of this kind, see Dr. Routh's paper on 'The Causes of the Endemic Puerperal Fever of Vienna,' in the "Medico-Chirurgical Transactions," vol. xxxii. p. 27.—That the poison which developes puerperal fever, may be conveyed from patients labouring under almost any other form of Zymotic disease tending to putrescence, that is propagable by contact,—such as scarlatina, small-pox, or erysipelas,—is now the general opinion of most practitioners who have paid special attention to the subject.

† This is shown by the instances, unhappily of no unfrequent occurrence, in which practitioners who have unfortunately become the vehicles of the puerperal poison, and have conveyed it to several patients in succession, have experienced the same direful results immediately on resuming obstetric attendance, after a lengthened interval of suspension from it, and even from professional employment of every kind.

‡ See Prof. Simpson 'On the Analogy between Puerperal and Surgical Fever,' in the "Edinb. Monthly Journ." vol. xi. p. 414; and vol. xiii. p. 72.

§ It is well known to Indian Medical Officers, that the liability to Fever, Dysentery, Cholera, &c. is very much increased *during*, and for some time *after*, a severe march. For a very striking example of the influence of this condition, concurrently with overcrowding, in producing a terrible augmentation in the fatality of Cholera, see "Brit. and For. Med.-Chir. Rev." vol. ii. pp. 80-90.

an accumulation is prone to take place, either when there are special sources of an augmented production, or when the excretory operations are imperfectly performed. And it would further appear, that the continued accumulation of such matters may itself become a source of certain forms of Zymotic disease, which may thus originate *de novo* in the system, and which may thence be propagated to other individuals in some of the modes already specified; of this we have notable examples in hydrophobia, erysipelas, and the 'pustule maligne.'

211. It is not only, however, in the class of Zymotic diseases, that we seem distinctly able to trace the operation of morbid poisons circulating in the blood; for there are numerous other maladies, of whose origin in a like condition there can be no reasonable doubt; and these are in some respects more closely analogous than the preceding, to the disordered states induced by the introduction of toxic agents. For in those of which we have now to speak, the action is destitute of any analogy to fermentation, and its potency is strictly proportionate, in each case, to the amount of the dose that is in operation. Here, too, we have a connecting link afforded by those disordered states of the system, which depend upon an undue accumulation of poisons normally generated within it, in consequence of some obstacle to their elimination. Thus, the train of symptoms which is consequent upon the retention of urea in the blood, so much resembles that occasioned by the ingestion of opium, as to have actually been mistaken for it; and is as true an instance of 'poisoning,' as if urea had been injected into the blood-vessels. So, in the asphyxia, which is produced by any obstruction to the extrication of carbonic acid through the lungs, the subject of it is as much 'poisoned,' as if he had inhaled carbonic acid from without. Again, the retention of the uric acid, biliary matter, lactic acid, and other substances which are normal products of the waste or disintegration of the body, is capable of becoming a source of morbid action in the system generally; and the evil is of course increased, when (as frequently happens) augmented production is concurrent with imperfect elimination. But perversions of the ordinary disintegrating processes are also far from being uncommon, whereby, instead of the substances already referred to, other products are engendered, whose presence in the circulating current gives rise to trains of symptoms altogether different. Of this class we seem to have an example in gout and rheumatism; the *materies morbi* of which diseases, though probably not identical with lithic and lactic acids, would seem to be formed from the decomposing matters which might normally have generated them. There can be no doubt, again, that many chronic diseases of nutrition are attributable to a similar cause; this being indicated by the *symmetrical* mode in which they affect the particular parts whose condition is altered (§ 201).

212. In all cases, therefore, one of the first questions which the intelligent Practitioner will feel called upon to decide, is, whether the malady he has to treat have its origin in the blood, or in a disorder purely local; and, if he feel justified in referring it to the blood, whether it merely depend upon an alteration in the proportion of its normal constituents, as in plethora and simple anæmia, or whether its phenomena imply the presence of some toxic substance in the circulating fluid.—If the former be his conclusion, he has then to endeavour to rectify the excess or the

deficiency, by reducing the former, or by supplying the latter; as when he bleeds and prescribes low diet for plethora, and employs iron and generous living in anæmia. But it is his duty to take care that his means are appropriate to his ends; and especially to abstain, when endeavouring to draw off an excess of one constituent, from doing serious injury by reducing another which may be already below par, and of which the presence may be essential to enable the system to resist the further progress of the malady. Thus, as we have seen, blood-letting has no decided effect in lowering the proportion of fibrin in the blood, whilst it has a most direct influence in reducing the number of red corpuscles; and there can be little doubt that the too-copious venesection which was formerly practised almost indiscriminately in acute inflammations, had a most decided influence in postponing the final recovery from them, whilst it had often but a doubtful efficacy in subduing the first violence of the disease. As a general rule it may be stated, that general blood-letting is likely to be rather injurious than beneficial in *toxic* inflammations, in which the vitality of the blood as a whole is decidedly lowered, notwithstanding the large increase in the proportion of fibrin; and to this rule, the results of careful and extended observation have recently shown that Rheumatism is seldom to be considered an exception, notwithstanding that this disease was formerly considered to be one of those, in which the efficacy of copious depletion was most undoubted. — In diseases of *toxic* origin, the treatment must be conducted upon principles exactly the same as those by which the practitioner would be guided in his treatment of a case of ordinary poisoning; but as regards the two classes into which it has been shown that these maladies may be divided, a difference must be made in their application.

213. The 'morbid poisons' of our second class (§ 211) are distinguished by this, that there is a continual *new generation* of them within the system; and the first indication of treatment, therefore, will be to check their formation, so far as this may be possible. This is the *rationale* of the dietetic and regiminal treatment of the lithic, lactic, and oxalic diatheses, of lepra and psoriasis, of chronic gout and rheumatism, and many other chronic diseases of toxic origin.—Secondly, we should endeavour to destroy or neutralize the poison, if we have any remedies which possess such an action upon it. Perhaps the curative influence of arsenic in some of the chronic skin-diseases, is one of the best examples of this kind; but it must be admitted that such direct 'antidotes' to morbid poisons are very few in number.—Thirdly, where we cannot thus destroy the poison, we must endeavour to moderate its action upon the system; this is the *rationale* of *palliative* treatment of every description, in which the *fons et origo* of the malady is left unchanged.—But fourthly, our main object must be to eliminate the poison from the system as rapidly as possible, by the various channels of excretion; acting upon these by remedies which will increase their activity, or which will so alter the condition of the morbific matter, as to enable it to be more readily drawn-off. The judgment of the well-informed practitioner, in the treatment of diseases of this class, is more shown in his discriminative selection of the best means of thus aiding the Blood to regain its normal purity, than in any more apparently 'heroic measures'; and a candid review of the most approved systems of treatment for diseases of the type here

alluded to, will show that the ratio of their efficacy is in accordance with that of their harmony with the above indications.

214. In the toxic diseases of the *zymotic* class, in most of which the poison is introduced from without, the course of the morbid phenomena to which it gives rise is usually more definite and specific, and its duration more limited. There is no source within the system, whence a new supply of the poison is continually arising; and its operation ceases, therefore, as soon as it is entirely eliminated from the system. But there is this peculiarity in the action of many of the poisons in question, that they have the power of multiplying themselves within the body; thus, for example, when small-pox has been communicated by the inoculation of an excessively minute portion of the virus, hundreds or thousands of pustules are generated, each of them charged with a poison equally potent with that from which they originated. It is to this multiplication, that the extension of zymotic diseases, by communication between individuals affected with them and healthy subjects, is chiefly due; and the question of the 'contagion' or 'non-contagion' of any particular disease of this class, is, therefore, essentially that of the multiplication or non-multiplication of the poison in the human body. This multiplication of certain zymotic poisons is a yet stronger point of analogy to the action of ferments, than that which is afforded by the violence of the changes they induce, when compared with the amount in operation. Some of these poisons are of such potency, that, in however minute a quantity they are introduced, they will change the whole mass of the blood in a few minutes; and will act indiscriminately on all individuals alike; this is the case, for example, with the venom of serpents. On the other hand, there are many (as already remarked) which seem to require the presence of some special fermentible matter in the blood (§ 210). And between these might probably be established a regular gradation,—from those most 'pernicious' forms of malarious poison which derive their potency from the intensity of vegetable decomposition under the influence of a high temperature, and those 'malignant' types of typhoid poison which owe their special intensity to animal putrescence engendered by filth and overcrowding, both of these attacking a very large proportion of those who are exposed to them,—to those milder forms of zymotic poisons, which, though derived from the same sources with the preceding, act with so much less of uniformity upon different individuals, that we can scarcely fail to recognize, as a 'predisposing cause' or rather as a necessary concurrent condition, the presence of some readily-decomposable matter in the blood. The long-continued action of these poisons, in their milder forms, seems itself capable of inducing this condition; thus, a healthy person who settles in an aguish country, may remain free from intermittent fever for a considerable time, but his health gradually deteriorates, and at last he becomes the subject of the disease, which would have much earlier attacked him if his blood had been brought into the 'fermentible' state by irregularity of diet, over-exertion, &c.; and the same may be observed in the case of those long exposed to the poison of typhoid or other fevers, which specially locates itself in animal miasmata, if not actually engendered by them.

215. In some of the diseases of this class, the change in the qualities of the blood produced by the introduction of the poison, is such as to

give it a morbid action on certain organs or tissues only; their phenomena in this respect corresponding with those of ordinary poisons, and of the toxic diseases previously noticed. Such may be said of hydrophobia, vaccinia, gonorrhœa, primary syphilis, &c., in which the general functions of the body are disturbed chiefly or solely through the local disorder. But, in other cases, we find that the contamination of the blood is such as to produce more or less disturbance in all the functions; as we especially witness in the severer forms of fever, in poisoning by venomous serpents, &c. Even in this last class of cases, however, a special determination to one organ or system is frequently obvious; and this may either be so constant as to be characteristic of the disease, which is the case with the skin-affection in the Exanthemata; or it may be chiefly directed by the previous condition of the patient's system, that organ or tissue (amongst those on which the poison is capable of acting) being most affected, whose previous nutrition was least healthy, as appears in the variety of local affections that are developed during an epidemic Influenza. This local determination may frequently be regarded as one of the means whereby the blood and the system at large are freed from the action of the poison; of this we have a most characteristic example in the Exanthemata. For it is a matter of constant observation, that constitutional symptoms, especially the fever and delirium, are most severe *before* the cutaneous eruption comes out; that there is much greater danger to life, when the eruption does not develope itself fully; and that its premature repression induces a return of the severer constitutional affection. It may be objected to this general statement, that, as the severity of small-pox usually bears a constant ratio to the amount of the cutaneous eruption, this cannot be regarded as relieving the blood of a poisonous impregnation; but it is to be borne in mind, on the one hand, that the confluence of the pustules greatly impedes the normal functions of the skin, whereby the constitutional disturbance is most seriously aggravated, their suspension, if complete, being itself adequate to destroy life; and besides this, the excessive development of the eruption is an indication that the poison has either possessed an extraordinary potency, or has found within the blood a material peculiarly favourable for its development. A similar example of a local affection, apparently originating in an eliminative determination of the poison to a particular organ, but sometimes increasing to such an extent as itself to become a serious and even fatal lesion, is afforded by the inflammation and ulceration of the Peyerian glandulæ in various zymotic diseases.*

216. In nearly all the toxic diseases of this class, there is a natural tendency to the self-elimination of the poison and of the products of its action on the blood, either by the operation of the ordinary excretory organs, or by the peculiar local actions just adverted to; and this process takes place in many instances with such regularity, that the time which it will require may be almost exactly predicted. There is not, in fact, a more remarkable indication of the 'Life of the Blood,' than is afforded by its extraordinary power of self-recovery, after having undergone the excessive perversion which is consequent upon the introduction of the more potent zymotic poisons; and every philosophical physician is ready to admit, that

* See Dr. Williams's "Principles of Medicine," 2nd edit. p. 248.

it is to this 'vis medicatrix naturæ,' rather than to any remedial agency which it is in his power to apply, that he must look for the restoration of his patient. The very nature of the action of zymotic poisons upon the blood, seems to forbid the expectation of our being able to neutralize or check that action by antidotes; and the objects of treatment wholly lie, therefore, in promoting the elimination of the morbific matters thus engendered, in keeping-under any dangerous excess of local action, and in supporting the system during the continuance of the malady. In a large proportion of zymotic diseases, it is probable that the oxidation of the morbific matter by the aeration of the blood, is the chief means of its removal; and it is accordant with this view, that the encouragement of the respiratory function, both pulmonary and cutaneous, by a pure and cool atmosphere, and by keeping the skin moist (either by the administration of diaphoretic medicines or by external applications) should be found one of the most efficient means of promoting recovery.* Whilst mild purgatives may be employed with advantage for the same end, in the earlier stages of these diseases, care must be taken that the system be not too much debilitated by their action; and the same caution must be observed with regard to the use of local depletion or counter-irritation, for the purpose of subduing the violence of some local affection. In fact, the general tendency of these diseases to the *adynamic* type, seems to indicate that, however beneficial the immediate results of reducing treatment may appear to be, its remote effects are much to be dreaded. And when the results of a large and varied experience are brought together, the Author believes that those will be found most satisfactory, in which the treatment has been *moderately* evacuant, and *early* sustentative.†

## CHAPTER V.

### OF THE PRIMARY TISSUES OF THE HUMAN BODY; THEIR STRUCTURE, COMPOSITION, AND ACTIONS.

217. The elementary Cells, Membranes, and Fibres, of which a general description has been given in a preceding chapter, are combined with each other in various modes, and are subjected to various metamorphoses, to form those different types of Organic Structure, to which the name of Primary Tissues is given. These may be seen to evolve themselves gradually from that homogeneous mass of cells, of which the fabric of the embryo is originally composed; each tissue becoming more unlike the rest in structure and properties, as it advances in its development; but yet presenting, even in its most complete and perfected state, no endow-

* Dr. Daniell, whose long familiarity with the most pernicious forms of African fever, and with the various modes of treatment which have been put in practice for its cure, gives a most decided preference to the *sudorific* system in vogue among the natives, as having a vast superiority over the venesections, saline purgatives, and large doses of calomel, which most European practitioners have employed. See his "Sketches of the Medical Topography and Native Diseases of the Gulf of Guinea," p. 120.

† On the subject of the latter portion of this section, the treatise of the late Dr. Robert Williams on "Morbid Poisons," and the "Principles of Medicine" of Dr. Charles J. B. Williams, may be studied with great advantage.

ments which are not referable to those of the simple primordial cells from which it originated. By this developmental process, in fact, a structure is formed, in which every separate part has a distinct office to perform; and it is this complete 'specialization,' or 'division of labour,' which constitutes the highest degree of organization. In every such fabric, however, each part lives, not only for itself, but also for every other part; for this very specialization, whilst it involves the increase of some particular form of vital endowment, involves also the decrease of others (§ 113); and hence it comes to pass, that the sum of the operations necessary for the maintenance of the life of even a single cell, in the conditions amidst which Man is placed, can only be performed by the totality of his entire organism, all the parts of which are mutually dependent upon one another. Thus, the life of his Nervo-Muscular apparatus, which may be considered as the most essential part of his fabric, cannot be sustained except by nutritive material prepared and conveyed to it by the organs of Digestion and Circulation, and would soon cease if provision were not also made for conveying away the products of its disintegration, by the various instruments of Excretion; whilst, on the other hand, the appropriation, preparation, and ingestion of food, the sustenance of the respiratory changes, and many other actions essential to the preparation and purification of the *pabulum* of the Nervo-Muscular apparatus, require the assistance of movements which it alone is competent to execute.—As the properties which the Primary Tissues possess in common have been already considered (CHAP. III.), we have now to inquire into those by which they are severally distinguished; and to trace out, so far as may be, the mode in which their special types of structure and endowment are respectively evolved, from those more general forms in which they all originate.

218. In a purely *anatomical* classification, the order in which these Tissues would be most appropriately arranged, would doubtless be that of their relation to the primitive types already described; but such a classification, strictly followed out, would involve so many physiological incongruities, as to render it unsuitable to our present purpose. For the particular office which each tissue performs in the vital economy, depends, not upon its own structure and endowments alone, but upon its position in reference to that of others; and thus, if we grouped together all the tissues consisting of unaltered cells, we should find a certain set adapted to introduce nourishment into the blood from the contents of the alimentary canal, in virtue of their position, and of their inherent power of selection and appropriation; whilst another set, drawing a similar material out of the blood, converts it into a portion of the solid fabric; and a third, by the exercise of the very same powers, removes from the circulating fluid the final products of the retrograde metamorphosis of the histogenetic substances, and pours them back (it may be) into the very cavity from which those substances were originally drawn.—If, on the other hand, we were to consider these Tissues in their *physiological* aspect only, as the instruments of so many distinct classes of operations, which all concur in the maintenance of the general life of the organism, we might be led to attach too little importance to their fundamental relations to each other and to the primitive forms out of which they are developed. Hence it will be advisable, in this as in a former instance (CHAP. II.), to adopt a mixed

classification, which may, so far as practicable, serve both purposes; and the Primary Tissues of the Human Body will be arranged, therefore, under the following heads.

I. The *Simple Fibrous Tissues,* including the elementary forms known as the 'white' and 'yellow' fibrous tissues, and the various combinations and arrangements of these, which are known as *Areolar* or 'connective' tissue, *Tendons, Ligaments, Aponeuroses,* &c.; all serving purposes of a purely mechanical nature.

II. The *Fibro-Cellular Membranes,* which are composite structures, made up of textures formed by interwoven fibres, of simple basement-membrane covering the surface of these, and of one or more layers of cells upon the free surface of the basement-membrane; such are the *Skin* investing the exterior of the body, the *Mucous Membranes* which are prolonged from the skin through all its open cavities, and the *Serous* and *Synovial Membranes* which line the closed cavities. With the Skin it will obviously be proper to consider the 'epidermic appendages,' namely the *Hair* and *Nails;* whilst with the Mucous Membranes, the *Glandular apparatus* is no less naturally connected.

III. Those purely *Cellular Tissues,* which form part of the interior fabric; of these the *Adipose* and the *Cartilaginous* are the types.

IV. The 'sclerous' tissues, *Bones* and *Teeth,* which are composed of an animal basis that is partly fibrous, partly cellular, consolidated by calcareous deposit.

V. The *Tubular Tissues,* which serve for the conveyance of liquids through the other tissues; namely, the *Blood-vessels* and *Absorbents.*

VI. The *Muscular Tissue,* which is specially distinguished by its contractile power; one form of it being composed of elongated primitive cells, the other of parent-cells elongated or coalesced into tubes, within which are aggregations of minute secondary cells.

VII. The *Nervous Tissue,* which, like the preceding, is rather distinguished by its vital endowments, than by the peculiarity of its organic structure; for it partly consists of simple cells, whilst another part of it is formed by cells elongated or coalesced into tubes.

### 1. *Of the Simple Fibrous Tissues.*

219. The various components of the Vegetable fabric,—its cells, tubes, woody fibres (or elongated cells), &c., being destined to retain their relative situations throughout their entire existence, are held together by simple adhesion; a gummy intercellular substance, which answers the purpose of a cement, being often interposed, sometimes in considerable quantity. But in the Animal body, of which the several parts are designed to move with greater or less freedom upon one another, the aggregations of cells that make up its chief part, either in their original or in their metamorphic form, could not be held together in their constantly-varying relative positions, without some intervening substance of an altogether different character. It must be capable of resisting tension with considerable firmness and elasticity; it must admit free movement of the several parts upon one another; and it must still hold them sufficiently close together, to resist any injurious strain upon the delicate vessels, nerves, &c., which pass from one to another, as well as to prevent

any permanent displacement. Now all these offices are performed in a remarkably complete degree, by the Areolar Tissue (§ 222); the reason of whose restriction to the Animal kingdom is thus evident. And as necessity arises, in certain parts, for tissues which shall exercise a still greater power of resistance to tension, and which shall thus communicate motion (as in the case of Tendons), or shall bind together organs that require to be united (as in the case of Ligaments and Fibrous Membranes), so do we find peculiar tissues developed, that serve these purposes in the most effectual manner. Hence these tissues also, although not endowed with any properties that are peculiarly *animal*, are nevertheless restricted to the Animal Kingdom,—as completely as are the Muscular and Nervous Tissues, which make up the essential parts of the apparatus of Animal Life.

220. These two qualities,—that of resistance to tension without any yielding,—and that of resistance combined with elasticity,—are characteristic of two distinct forms of Fibrous tissue; and these are distinguished, by the hue which they ordinarily present, as the *White* and the *Yellow*.—The *White* presents itself in the form of inelastic bands of variable size, the largest 1-500th of an inch in breadth, somewhat wavy in their direction, and marked longitudinally by numerous streaks (Fig. 14); these streaks are rather the indications of a longitudinal creasing, than a true separation into component fibres; for it is impossible by any art to tear up the band into filaments of a determinate size, although it manifests a decided tendency to tear lengthwise. Sometimes, however, distinct fibres may be traced, whose diameter varies from about 1-15,000th to 1-20,000th of an inch.—This tissue is entirely resolved into Gelatin (§ 33) by sufficiently prolonged boiling. When treated with Acetic acid under the microscope, it swells up and becomes transparent; and certain oval corpuscles are then brought into view, which seem to be either the nuclei of the cells that were concerned in the formation of this tissue, or the free nuclei of the blastema by whose fibrillation it was produced (§§ 223, 224).—This tissue is nearly the sole component of Tendons, Ligaments, Fibrous Membranes, Aponeuroses, &c., all of which present the arrangement already described, with very little modification, save that the bands are often but slightly wavy, and are sometimes even quite straight. If the traction to be resisted should be applicable in one direction only, as is the case in Tendons and in most Ligaments, we find the bands or fasciculi of fibres arranged side by side with considerable regularity; and the larger tendons are shown by transverse section to be made up of numerous aggregations of this kind, which are held together, whilst to a certain degree kept apart from one another, by the interposition of Areolar tissue. When, however, the traction is liable to be exercised in various directions, the fasciculi of primitive fibres are observed to cross each other obliquely; this decussation is observable

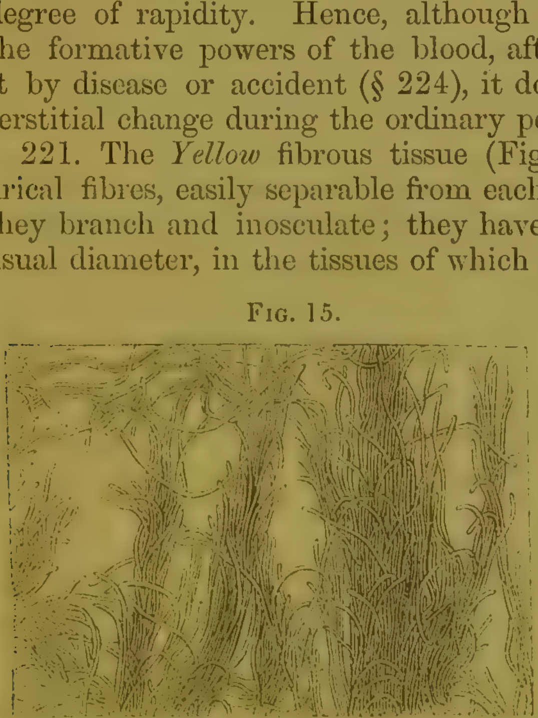
Fig. 14.

White Fibrous Tissue from Ligament. Magnified 65 diameters.

in many ligaments, but still more in those fibrous structures which serve as protective capsules to softer organs. This tissue receives very few blood-vessels, and still fewer nerves; indeed it seems doubtful whether, in many fibrous structures (as tendons), nerves are normally present at all, except on the sheaths of the blood-vessels. From the time when it has attained its complete development, this tissue seems entirely destitute of any vital endowment, and its physical actions are not of a kind to induce disintegrating changes in its substance, with any considerable degree of rapidity. Hence, although it is very rapidly regenerated by the formative powers of the blood, after the destruction of a portion of it by disease or accident (§ 224), it does not seem to undergo much interstitial change during the ordinary performance of its functions.

221. The *Yellow* fibrous tissue (Fig. 15) exists in the form of cylindrical fibres, easily separable from each other longitudinally, except when they branch and inosculate; they have a dark decided border; and their usual diameter, in the tissues of which they are the principal components, is about 1-7500th of an inch, though they are sometimes nearly double, and sometimes scarcely one quarter of that thickness. One of their most marked peculiarities is their tendency to break off abruptly, the broken ends curling back upon themselves; and this suggests the idea that they are composed of linear aggregations of particles of a very definite character.* The composition of this tissue is very different from that of the white; for it is but little changed by long boiling; and although the decoction slightly gelatinizes on cooling, yet the small amount of gelatin thus indicated is probably derived from the white fibrous element of the areolar tissue, with which the elastic tissue is usually penetrated. It is unaffected by the weaker acids, and undergoes no solution in the gastric fluid; and it preserves its elasticity for an almost unlimited period. According to Scherer, the yellow fibrous tissue from the middle coat of the arteries consists of 48 C, 38 H, 6 N, 16 O; which (taking Liebig's formula for Protein) may be regarded as 1 Protein + 2 Water. When burned, it leaves 1·7 per cent. of ash. It is always readily distinguished from the white fibrous tissue, under the microscope, by its complete resistance to acetic acid. There is less tendency to spontaneous decomposition in this tissue, than in any other of the soft and moist portions of the fabric. It requires but little renovation, therefore, by the nutritive operations; since it seems to possess no further vital activity when

FIG. 15.



Yellow Fibrous Tissue, from Ligamentum Nuchæ of Calf. Magnified 65 diameters.

* In the ligamentum nuchæ of the Giraffe, indeed, the fibres are marked with peculiar transverse striations, strongly resembling those of the hairs of the Mouse and other Rodents, and, as in them, probably indicative of a cellular organization. (See Mr. Quekett's "Catalogue of the Histological Series contained in the Museum of the Royal College of Surgeons of England," vol. i. pl. v. fig. 10.)

once it is fully developed, and the exercise of its physical properties will involve but little disintegration. Accordingly, it is but very sparingly supplied with blood-vessels, and no nerves have been traced into its substance.—This tissue makes up the principal part of the Ligamenta subflava, which extend between the arches of the adjacent vertebræ, connecting them together, but still allowing them considerable 'play;' it also forms a large portion of the middle or fibrous coat of the Arteries; and the Chordæ vocales, and some other ligaments of the larynx, are almost entirely composed of it. In all these situations, elasticity is the property which is particularly required; and the structures enumerated are among the most elastic of all known substances, recovering this attribute upon being moistened, after having been kept in a dried state for an unlimited period.

222. A very large proportion of the body, in Man as in all the higher Animals, is composed of a tissue, to which the name of 'cellular' was formerly given. This term, however, is so much more applicable to those structures which are composed of a congeries of distinct cells, and the use of it for both purposes is so likely to engender confusion, that it is to be wished that its application to this texture should be altogether discontinued.—The tissue in question, now generally designated the *Areolar*, is found, when examined under the Microscope, to consist of a network of minute fibres and bands, interwoven in every direction (Fig. 16), so as to leave innumerable interstices, which communicate freely with each other. These fibres and bands are composed in part of the White and in part of the Yellow fibrous element; and the proportion of the two varies with the degree of elasticity which may be required for the special purpose which the tissue is destined to serve in each situation.* The proportion between them is easily determined by the use of acetic acid, which renders the white so transparent as to be invisible, and thus brings the yellow into full distinctness. Sometimes the elastic fibres are observed, not merely to interlace with the white, but to pass round their fasciculi, constricting them with distinct rings or with a continuous spiral; this remarkable disposition is best seen in the areolar tissue that accompanies the arteries at the base of the brain. This tissue yields gelatin on boiling, in virtue of the White fibrous structure of which it is chiefly composed. Its interstices are filled during life with a fluid, which resembles a very dilute Serum of the blood; it consists chiefly of water, but contains a sensible quantity of common salt and albumen, and (when concentrated) a trace of alkali sufficient to affect test-paper. The presence of this fluid seems to result from an act of simple physical *transudation;* for it has been found that, when the serum of the blood is made to percolate through thin animal membranes, the water charged with saline matter

Fig. 16.

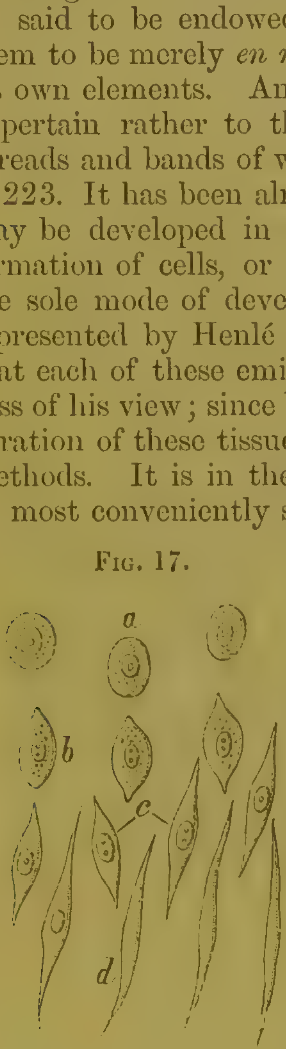
Arrangement of Fibres in Areolar Tissue. Magnified 135 diameters.

* The discovery that the Areolar tissue is not a peculiar elementary form, but a combination of the two elements previously described, was first made by Messrs. Todd and Bowman, and announced in their excellent "Physiological Anatomy," vol. i. p. 73.

passes through them much more readily than the albumen, a part of which is kept back (§ 227).—The great use of Areolar tissue appears to be, to connect together organs and parts of organs, which require a certain degree of motion upon one another: and to envelope, fix, and protect the blood-vessels, nerves, and lymphatics with which these organs are to be supplied. It can scarcely be said to enjoy any *vital* powers, and is connected solely with physical actions (§ 134). It is extensible in all directions, and very elastic, in virtue of the physical arrangement of its elements; and it possesses no contractility, except that which it derives from the smooth muscular fibre-cells (Fig. 79) which are frequently intermingled with its other elements, sometimes very copiously. It cannot be said to be endowed with sensibility; for the nerves which it contains seem to be merely *en route* to other organs, and not to be distributed to its own elements. And its asserted powers of absorption and secretion appertain rather to the walls of its capillary blood-vessels, than to the threads and bands of which it is itself composed.

223. It has been already mentioned (§ 118) that the foregoing tissues may be developed in two different modes; namely, either by the transformation of cells, or by the fibrillation of a blastema. The former was the sole mode of development assigned by Schwann, and the latter was represented by Henlé in the same light; but other observers have shown that each of these eminent histologists was correct, save in the exclusiveness of his view; since both the first development and the subsequent regeneration of these tissues have been seen to take place after either of these methods. It is in their reproduction after injury, that the process may be most conveniently studied; and the following account of it is founded on the statements of Mr. Paget,* who has specially attended to this inquiry.—The development of White fibrous tissue, in the form of Areolar texture, from cells, may be observed in the material of granulations, or in that of inflammatory adhesions and indurations. The cells first formed in the plastic exudation are round, very slightly granular, from 1-1500th to 1-2000th of an inch in diameter; they have a distinct cell-wall, which is readily brought into view by the action of water, if not apparent at first; and they present a round dark-edged nucleus, whose sharp definition distinguishes it from that of the colourless corpuscles of the blood, to which these cells otherwise bear a close resemblance. It is in this nucleus that the first developmental change shows itself, for it assumes an oval form, and its substance becomes clearer and brighter. Very soon, however, the cell itself elongates at one or both ends, so as to assume the caudate, fusiform, or lanceolate shape (Fig. 17); and its contents become more minutely and distinctly granular, whilst the cell-wall thins away or becomes blended with its enclosure. As the cells elongate more

Fig. 17.




Development of fibres from cells:—*a*, circular or oval nucleated cells; *b*, the same becoming pointed; *c*, the same become fusiform, the nuclei being still apparent; *d*, the same elongated into fibres, the nuclei having disappeared.

* 'Lectures on the Processes of Repair and Reproduction after Injuries,' in "Medical Gazette," 1849, vol. xliii. pp. 1069-1071.

and more, so as to assume the filamentous form, they also arrange themselves in such a manner, that the thickest portion of one is engaged between the thinner ends of the two or more adjacent to it; and thus fasciculi are gradually formed, of which every fibre is developed from one elongated cell, except where two or more cells have united end-to-end, so as to form one long continuous filament.* In the production of areolar tissue in inflammatory exudations or in granulating wounds, the nuclei of these fibre-cells appear to waste and be absorbed; but in the normal course of development, which may be seen to take place on this plan in the subcutaneous areolar tissue of the fœtus, as well as in many other situations, it is probable that they develope themselves into the 'nuclear fibres' of Henlé, which constitute, in fact, the Yellow or elastic filaments that are intermingled with the white in this tissue.

224. The development of the White fibrous tissue by the fibrillation of a nucleated blastema, without any intervening cell-formation, may be observed in the organization of the material by which the filling-up of subcutaneous wounds is usually accomplished; and seems to be the mode in which the first production of tendons and ligaments is normally accomplished. The blastema, when first effused, seems like a mere fibrinous exudation, usually containing a quantity of finely-molecular or dimly-shaded substance, but having no appearance of distinct nuclei; these, however, gradually present themselves in it, as if they were formed by the aggregation of molecules; and they presently appear as oval bodies with dark hard outlines, which soon become elongated, and are so firmly imbedded in the surrounding substance, that they can scarcely be dislodged. The blastema gradually acquires a more and more distinct fibrous appearance, and at last exhibits a regular filamentous structure; the nuclei themselves undergoing little change during this time, but appearing to govern the direction of the fibrillation. As the texture goes on to completion, the nuclei are either absorbed, which seems to be the case in the connecting tissue formed for the reparation of injuries, as well as in the normal development of tendons; or they undergo a further development into 'nuclear fibres.' † This is effected by their extension at both ends, so that the nuclei thus prolonged meet and unite; their particles taking-on that very uniform linear arrangement, by which the fibres of this tissue seem to be characterized; and sometimes perhaps undergoing a partial or complete development into cells (§ 221).—The rate at which the production of fibrous tissue takes place in the manner now described, is at first very rapid; well-marked filaments being detectable in the blastema within seven or eight days; and the tenacity of the bond thus formed between the two ends of a divided tendon is such, that, in one of Mr. Paget's experiments, within ten days after the operation, the reunited tendo-Achillis of a rabbit (the new tissue being a cord of not more than two lines in its chief diameter) supported a weight of above fifty pounds. The subsequent changes take place more slowly; but the reparation of divided tendons has been found to be so complete within five months after the operation, that no trace of

* It was asserted by Schwann that each of these elongated cells splits up into several filaments; but Mr. Paget agrees with many other observers in considering this representation erroneous.

† See Henlé's "Allgemeine Anatomie," traduit par Jourdain, tom. i. pp. 202, 406.

the sections could be discovered even by microscopic examination.—It is important to observe that the blastema which undergoes this self-organization, is *not* an inflammatory exudation, but one which is much better adapted for the reparative process. For, as Mr. Paget has observed, in experimenting upon the subcutaneous division of tendons, the effusion which is first poured forth after the shock of the injury contains exudation-cells, which begin to undergo the changes described in the preceding paragraph, but are not developed beyond the state in which they appear spindle-shaped. And it is not until about forty-eight hours have elapsed (in the rabbit), that the true reparative material begins to appear. This material must be looked upon as having undergone a much higher elaboration than the inflammatory exudation has received; since it can at once pass on to that ultimate condition, which is only attained in the other case by an intermediate process of cell-life. But we can scarcely fail to recognize, also, the influence of the healthful condition of the surrounding tissues, in promoting development by the vital force which they impart (§ 27); the state of inflammation being essentially one of diminished vitality of the solid tissues, and its existence therefore rendering them less liable to promote the organization of the plastic material thrown out in their proximity. Accordingly we shall find hereafter (CHAP. XI. SECT. 3), that in proportion to the degree of the inflammatory change in the solids, does it tend to depress the vitality of the effused blastema, so as to retard or even to prevent its due development, and to occasion the degradation of the whole or of the greater part of it to the condition of pus.

225. At what precise time, or by what means, the *chemical* change occurs, by which the fibrinous constituents of the plastic exudation are converted into the gelatinous basis of the white fibrous tissue, we have no certain knowledge; there are indications that the process is a gradual one, and involves the existence of various intermediate gradations (§ 30); and a more attentive chemical examination of fibrous tissues in progress of formation, would probably throw considerable light upon the nature of the transition.—All that is known of this subject, however, indicates that the production of the gelatigenous tissues takes place solely at the expense of the fibrinous component of the blood; and that gelatin employed as food cannot become converted into fibrous tissue, except by passing through this intermediate condition, into which it is next to certain that it can never be transmuted. For although there is ample evidence of the conversion of the albuminous compounds into the gelatinous, into the living body, yet the reconversion of the gelatinous into the albuminous appears to be a complete impossibility. (See CHAP. VII.)

### 2. *Of the Fibro-Cellular Membranes, and their Appendages.*

226. The body of Man, in common with that of all the higher animals, contains numerous and extensive membranous expansions, which form its external investment and line its internal cavities, and which are consequently free or unattached on one of their surfaces, whilst the other is continuous with the tissues which they overlie. The principal part of the substance of all these membranes is made-up of the Simple Fibrous tissues described in the preceding section, interwoven so closely as to form a sort of condensed

areolar tissue, with which blood-vessels, lymphatics, nerves, and smooth muscular fibres may be blended in varying proportions. The fibres of this tissue are continuous with those of the looser texture that lies beneath its attached surface, and there is consequently no definite boundary to the membrane on that side. But the free surface is covered by a layer of basement-membrane, which forms a complete limit, not only to the fibres, but also to the vessels, nerves, &c., of the subjacent tissue. This membrane, it is true, cannot always be distinguished; but there is strong analogical ground for believing in the universality of its presence. Supported by this basement-membrane, and covering what would otherwise be its exposed face, we find one or more layers of cells; and these may have very different endowments in different situations, so as to impart very diversified characters to the surfaces which they form.—Whilst all the membranes now under consideration agree in consisting of the foregoing elements, they differ amongst each other in regard alike to the relative proportions of their components, and to the mode in which they are arranged. There are three principal categories, however, under which they are capable of being grouped together, viz., the *Skin*, the *Mucous Membranes* and the *Serous Membranes;*—the first of these forming the external integument; the second being continued from it at various points, so as to line all the open cavities of the body; and the third forming closed sacs, which intervene between surfaces that rub or glide one over the other. Of these, the Serous Membranes are the least distinguished by the speciality of their endowments; and they may, therefore, be advantageously considered in the first instance.

227. *Serous and Synovial Membranes.*—These membranes, which are so named from the nature of the fluid with which their free surface is moistened, are thin and transparent, so as to allow the colour of subjacent parts to be seen through them. They are endowed, however, with a considerable amount of strength, and possess much elasticity in situations where mobility is particularly required. Their free surface, which is smooth and glistening, is found, when examined with the microscope, to be covered with a single layer of flattened polygonal cells, usually of a tolerably regular hexagonal shape, constituting what is designated as a 'tesselated' or a 'pavement-epithelium' (§ 230); and beneath this, a layer of basement-membrane is affirmed by Messrs. Todd and Bowman to be clearly distinguishable.—The principal part of the substance of the membrane is composed of what may be considered as condensed areolar tissue, into which the yellow fibrous element largely enters, its filaments interlacing into a beautiful network, and thus imparting a high degree of elasticity to its texture. This gradually passes into that laxer variety, by which the membrane is attached to the parts it covers, and which is commonly known as the 'sub-serous' tissue; here fat-cells are not unfrequently found. The blood-vessels of Serous membranes usually have a simple plexiform arrangement, parallel to the surface, and are seldom very copious; but those of Synovial membranes are far more numerous, and their minutest ramifications are remarkable for their length and tortuosity (Fig. 43),—a disposition which seems to have reference to the nutrition of the Cartilage beneath. The Synovial membranes are further distinguished by the presence of numerous fringe-like processes, of extreme vascularity, hanging down loosely into the cavity of the joint;

these are covered with an epithelium of a very different character from that already described, its cells being large, spheroidal, and very loosely attached to the surface beneath; and there can be little doubt that they constitute the *secreting* apparatus for the synovial fluid. The *Bursæ* interposed between the prominences of bones and the tendons or integuments that glide over them, or amongst the tendons themselves, appear to be essentially similar to the synovial membranes in the arrangement of their elements; but their epithelium is less regular, and shows numerous gradations of cell-growth.—The fluid of the Serous sacs is normally only sufficient to keep their surfaces moist, and its composition in the healthy state is consequently indeterminable. In various abnormal conditions, however, it accumulates in large amount; and as this may occur from simple obstruction to the venous circulation, without any morbid affection of the membrane itself, it is probable that the fluid which thus transudes is very similar in quality to the natural serous exhalation. As a general rule, the fluid effused from Serous membranes resembles the serum of the blood with a considerable proportion of its albumen kept back, the salts being present in nearly their normal amount; the amount of albumen present, however, is subject to great variation, but the recent researches of Schmidt and Lehmann* have shown that it presents a remarkable degree of constancy in the exudations from each membrane. Thus, the transudation of the pleura contains about 2·85 per cent of albumen; that of the peritoneum only 1·13 per cent, that of arachnoid no more than 0·6 or 0·8 per cent, and that of the subcutaneous areolar tissue as little as 0·36 per cent. There is strong reason to believe that the retention of the chief part of the albumen, when the water and the salines transude the coats of the vessels, is merely the result of the physical arrangement of the elements of the membranes; it having been shown by Valentin,† that the filtration of albuminous fluid through dead serous membranes is attended with the same result. And it can scarcely be doubted, therefore, that the variation in the quantity allowed to pass by different membranes, is to be attributed to their physical peculiarities. In proportion to the increase of the pressure to which the blood may be subjected (as through an obstruction to its return, or any other cause), is the increase in the proportion of albumen which transudes; and in some cases of extreme obstruction, without inflammation, the presence of soft jelly-like masses or of strings of fibrin, indicates that even this component of the blood may be made to transude by a further augmentation of pressure.‡ The fluid of the Synovial capsules and of the Bursæ is of a much more viscid character, almost resembling oil in its glairy appearance, and not mixing readily with other liquids; its composition has not been precisely made out; but it certainly contains a far larger proportion of albuminous matter than the serous exudations, and it may be probably considered as a true product of secretion. The purpose of all these fluids is obviously to diminish friction between surfaces which are exposed to mutual attrition; and the quantity of albumen

* "Lehrbuch der Physiologischen Chemie," band ii. pp. 248–50.

† "Lehrbuch der Physiologie," band i. p. 601.

‡ This has been experimentally demonstrated by Mr. Robinson, who has shown that the urine may be rendered albuminous or even fibrinous by the application of a ligature round the renal vein. ("Medical Gazette," June 28, 1844).

they respectively contain seems to have reference to the amount of motion and of pressure to which the membranes are subjected, being least in the cavities of the brain, somewhat more in that of the peritoneum, two and a half times as much in that of the pleura, and many times greater in the synovial capsules.—It is probable that the rate of nutrition of the Serous membranes is not rapid under ordinary circumstances; since there appears to be but little vital activity in them. Their epithelium exhibits no indications of being frequently cast off and renewed, like that of many other parts; and is probably very permanent in its character. The membranes of the Synovial capsules and of the Bursæ, however, obviously possess a much higher vital activity, being themselves more vascular, and having an epithelium which is evidently in continual course of renewal; and this activity seems connected with their secretory office. All these membranes are very readily regenerated after loss of substance; and they are even produced *de novo*, when circumstances call for their existence. Thus we find regular synovial capsules formed around 'false joints,' and new bursæ developed between portions of the cutaneous surface exposed to much friction, and the subjacent bones. In all these cases, the cysts appear to originate in an enlargement and fusion of the normal interspaces of areolar tissue, and in a condensation of the tissue itself around the cavities thus formed. Serous membranes, when inflamed, are peculiarly prone to throw out plastic exudations, which become organized into 'false membranes;' and these frequently constitute 'adhesions' connecting their opposite surfaces. In this respect, however, the synovial membranes show a marked difference from the more general type; 'adhesive inflammation' being comparatively rare in them.*

228. *Mucous Membranes, and their Glandular appendages.*—The Mucous membranes, like the serous, derive their name from the attributes of the fluid with which they are moistened; this fluid, however, is not a mere exudation of the watery part of the blood, but is a regular secretion, peculiarly consistent and tenacious in its character, whose purpose is obviously protective. These membranes are usually thicker than the serous, and are more or less opaque; they possess, however, comparatively little tenacity; and the reddish colour which they exhibit, both during life and after death, is dependent on the blood contained in their copious blood-vessels, and may vary greatly in intensity, according to the degree in which these vessels are congested. There is relatively less fibrous tissue in these membranes than in the serous, a very large part of their substance being formed by blood-vessels and lymphatics; and there are some situations in which it is almost entirely wanting, as in the superficial stratum of the gastro-intestinal mucous membrane, where, immediately beneath the basement-membrane, we find the vessels spread out amidst a soft granular matter, with a few corpuscles resembling free nuclei and granule-cells.† The fibres of the deeper layer are continuous with those of the 'submucous' areolar tissue. The presence of a distinct basement-membrane cannot be always demonstrated,

* The anatomy and physiology of the Serous and Synovial Membranes have been ably treated of by Dr. Brinton, in his Article on that subject in the "Cyclopædia of Anatomy and Physiology," vol. iv. p. 510.

† See Dr. Sharpey, in "Quain's Elements of Anatomy," 5th edit. p. cclxxx.

especially where the membrane presents a simple even surface; but where the membrane is depressed into *follicles* (Fig. 18, F,F), or prolonged into *villi* (V,V′), the existence of the basement-membrane may usually be clearly made out, though it can seldom be separated from the subjacent tissue. The blood-vessels and lymphatics with which the Mucous membranes are copiously supplied, form a very minute and closely-set plexus which spreads out beneath the basement-membrane; advancing with it into the villi which it covers (Fig. 22), and surrounding the follicles which it lines (Fig. 23). The 'follicular' arrangement is very common in mucous membranes; the follicles being sometimes isolated from each other, and sometimes clustered so thickly that there is only room for blood-vessels and connective tissue between them. The 'villous' character, on the other hand, is for the most part limited to a portion of the

Fig. 18.

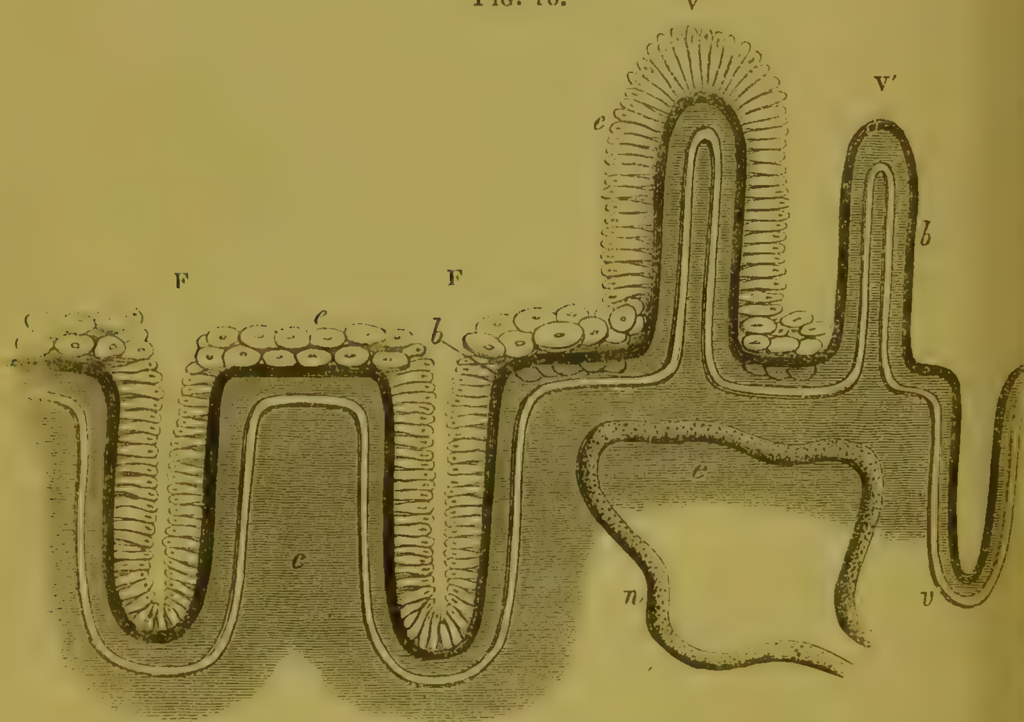



Diagram of the structure of an involuted Mucous Membrane, showing the continuation of its elements in the follicles and villi; F, F, two follicles; *b*, basement membrane; *c*, submucous tissue; *e*, epithelium; *v*, vascular layer; *n*, nerve; V, villus, covered with epithelium; V′, villus whose epithelium has been shed.

gastro-intestinal mucous membrane. The entire surface of the Mucous membranes is covered by an Epithelial layer (*e*), which not only lies upon their simple flat expansions, but also invests the villi and lines the follicles; the structural characters and physiological uses of this epithelium, however, are so different in different situations, and even in closely-adjacent parts of the same stratum, as to require a more special description (§ 230). These cells, instead of forming a comparatively permanent stratum, like the epithelium of serous membranes, are in a state of continual change and renewal; the older layers falling off, whilst new ones are produced from the surface or from the substance of the basement-membrane. It is chiefly on the bronchio-pulmonary and gastro-intestinal mucous membranes, that we meet with the peculiar secretion termed

*Mucus;* which appears to be expressly formed to shield these surfaces rom the irritation they would suffer, through the contact of air, or of olids or liquids. This secretion is also found on the lining membrane of he larger excretory ducts of most of the glands; and it is mixed in reater or less amount, with most of the secretions discharged by them. t is found also upon the lining membrane of the gall-bladder, and of the rinary bladder. When these membranes are in a state of unusual irri-ation, the amount of mucus which they discharge is very considerable; ut it ordinarily forms an extremely thin layer. The characters of Mucus, btained from various sources, are by no means invariable. In general, owever, it may be described as a fluid of peculiar viscidity, either colour-ess or slightly yellow, transparent or nearly so, incapable of mixing with vater, and sinking in it, except when buoyed up by bubbles entangled in ts mass, which is commonly the case with the bronchial and nasal mucus. This fluid contains from $4\frac{1}{2}$ to $6\frac{1}{2}$ per cent of solid matter, of which a mall part consists of salts resembling those of the blood; whilst the hief organic constituent is a substance termed *Mucin,* to which the haracteristic properties of the secretion are due. This appears to be an lbuminous compound, altered by the action of an alkali; for, as Dr. Babington has shown, any albuminous fluid may be made to present the eculiar viscidity of mucus, by treating it with liquor potassæ. That the nucin of Mucus is held in solution by an alkali, appears from this, that it s readily precipitated by acids, which neutralize the base; and that a sort f faint coagulation may be induced even by water, which withdraws the ase from it. When Mucus is examined with the Microscope, it is found o contain numerous epithelium-scales (or flattened cells); together with ound granular corpuscles, considerably larger than those of the blood, and losely resembling the nuclei of the epithelium-cells, which are commonly ermed mucus-corpuscles. In the more opaque mucus, discharged from nembranes in a state of irritation or inflammation, these corpuscles are resent in greatly-increased amount; and cells are often developed around hem.

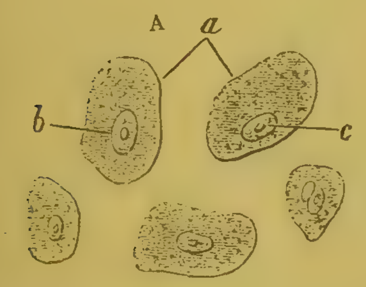
229. The essential character of the Mucous Membranes, in regard like to their offices and their arrangement, is altogether different from hat of the Serous and Synovial membranes. For, whilst the latter form hut sacs whose contents are destined to undergo little change, the former ne tubes and cavities which have free outward communications; and hey thus constitute the medium, through which nearly all the material hanges are effected, that take place between the living organism and the xternal world. Thus, in the gastro-intestinal mucous membrane, we nd a provision for reducing the food, by means of a solvent fluid poured ut from its follicles; whilst the villi, or root-like filaments, which are losely set upon its surface towards its upper part, are specially adapted o absorb the nutrient materials thus reduced to the liquid state. This ame membrane, at its lower part, constitutes an outlet through which re cast out, not merely the indigestible residuum of the food, but also he excretions from numerous minute glandulæ in the intestinal wall, which result from the decomposition of the tissues, and which must be eparated from them to prevent further decay. Again, the bronchio-pul-nonary mucous membrane serves for the introduction of oxygen from the ir, and for the exhalation of water and carbonic acid. And lastly, the

mucous membranes are continuous with the cell-lined vesicles or tubes of the various Glands, which are the instruments whereby their respective products are eliminated from the blood. — The changes to which the Mucous Membranes are thus subservient, however, do not seem to involve the vital activity of any other of their components than the Epithelial cells, and of the basement-membrane as probably ministering to their production. Here, as elsewhere, the fibrous elements appear to have but a passive relation to the vital operations of the tissue into which they enter; and there is no reason to think that the copious supply of blood which the mucous membranes receive has any relation to *their* nutrition. In fact, we might fairly describe the Mucous membranes generally as *essentially* consisting of a plexus of blood-vessels in immediate relation with a stratum of epithelial cells; the fibres having merely a connective office, and their absence not being in any way detrimental, if they be not required for this purpose. Thus, the tubuli and follicles of many glands are composed of a basement-membrane and epithelial layer, prolonged from those of the mucous membranes with which they are in connexion, and yet may have no fibrous tissue properly appertaining to them, being imbedded in the substance of the glands, and closely surrounded by blood-vessels. Mucous membranes are not, for the most part, copiously supplied with nerves, nor do they possess much sensibility; there are exceptions, however, chiefly in the case of those which, being near the inlets and outlets of the body, are endowed with sensibility, apparently for the purpose of guarding against the contact or admission of injurious substances (as in the case of the conjunctival, buccal, and laryngeal membranes), or of giving notice of the presence of excrementitious matters requiring ejection by muscular power (as in the case of the lining-membranes of the bladder and rectum). — Mucous membranes, when diseased, are far less disposed than the serous to throw out plastic exudations, but are prone to suppuration, ulceration, and gangrene. Their regeneration after loss of substance by disease or injury, takes place with great rapidity; but although a *simple* membrane may be completely restored, yet it appears from observation of the healing-process after ulcers of the large intestine, that the tubular follicles are not reproduced. A complete reproduction of the follicular structure takes place, however, in the lining membrane of the uterus, after its exuviation in the formation of the Decidua (CHAP. XIX.).—It is interesting to observe, that where a portion of the Cutaneous surface has been turned inwards, so as to form part of the boundary of one of the internal cavities (as in the plastic operations for the restoration of lips, eyelids, &c.), it undergoes a gradual modification in its characters, and comes, after a time, to present the appearance of an ordinary Mucous membrane.

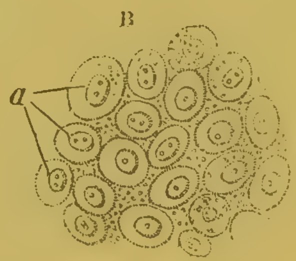
230. For our knowledge of the constant existence of the *Epithelium* as an integral constituent of the Mucous and Serous membranes, and for our appreciation of its important offices in the economy, we are entirely indebted to the assistance afforded by the Microscope. It had long been known that the epidermic layer might be traced continuously from the lips to the mucous membrane of the mouth, and thence down the œsophagus into the stomach; and that, in the strong muscular stomach or gizzard of the granivorous birds, it becomes quite a firm horny lining. But it has been only since the application of the Microscope to this in-

vestigation, that a continuous layer of cells has been traced, not merely along the whole surface of the mucous membrane lining the alimentary canal, but likewise along the free surfaces of all other Mucous Membranes, with their prolongations into follicles and glands; as well as on the Serous and Synovial membranes, and the lining membrane of the heart, blood-vessels, and absorbents. The forms presented by the *Epithelial* cells are various. The two chief, however, are the *tesselated*, forming the 'pavement-epithelium;' and the *cylindrical*, forming the 'cylinder-epithelium.' —The 'pavement-epithelium' covers the serous and synovial membranes, the lining membrane of the blood-vessels, and the ultimate follicles or tubuli of most glandular structures connected with the skin or mucous membranes, as also the mucous membranes themselves, where the cylinder-epithelium does not exist. The cells composing it are usually flattened (Fig. 19, A), and sometimes so polygonal as to come into contact with each other at their edges, like the pieces of a tesselated pave-

FIG. 19.



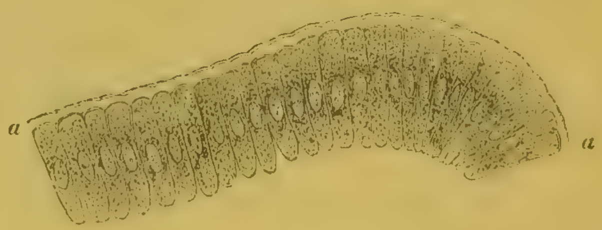

Separated Epithelium-cells, *a*, with nuclei, *b*, and nucleoli, *c*, from mucous membrane of the mouth.




Pavement-Epithelium of the Mucous Membrane of the smaller bronchial tubes; *a*, nuclei with double nucleoli.

ment (Fig. 12); but they sometimes retain their rounded or oval form, and are separated from each other by considerable interstices (Fig. 19, B). This last form seems to be the commonest, where the cells are most actively renewed, so that they have not time (so to speak) to be developed into a continuous stratum. The number of layers is commonly small; and usually there is only a single one.—The 'cylinder-epithelium' is very differently constituted. Its component cells are cylinders, which are arranged side by side (Fig. 20); one extremity of each cylinder resting upon the basement-membrane, whilst the other forms part of the free surface. The perfect cylindrical form is only shown, however, when the surface on which the cylinders rest is flat or nearly so. When it is *convex*, the lower ends or bases of the cells are of much smaller diameter than the upper or free extremities; and thus each has the form of a truncated *cone*, rather than of a cylinder; as is well seen on the cells covering the villi of the intestinal canal (Fig. 18). On the other hand,

FIG. 20.




Cylinder-Epithelium, from the intestinal villi of a rabbit; *a*, *a*, membrane connecting their free surfaces, rendered more distinct by the action of water.

where the cylinder-epithelium lies upon a *concave* surface, the free extremities of the cells may be smaller than those which are attached. Moreover, when it is very compactly arranged, its sides may be flattened against each other, so as to become polygonal; and this constitutes the *prismatic* variety. Sometimes each cylinder is formed from more than one cell, as is shown by its containing two or more nuclei; although its cavity seems to be continuous from end to end. And occasionally the cylinders arise by stalk-like prolongations, from a pavement-epithelium beneath. The two forms of Epithelium pass into one another at various points; and various transition-forms are then seen; the tesselated scales appearing to rise more and more from the surface, until they project as long-stalked cells, truncated cones, or cylinders. The cylinder-epithelium covers the mucous membrane of the alimentary canal, from the cardiac orifice downwards; it is found also in the larger ducts of most glands which open into that canal, or upon the external surface, such as the ductus choledochus, the salivary ducts, those of the prostate and Cowper's glands, the vas deferens, and the urethra. In all these situations, it comes into connexion with the pavement-epithelium, which usually lines the more delicate canals of the glands, as well as their terminal follicles. —There are certain parts, moreover, on which the Epithelial cells retain their primitive roundness, with very little modification; such cells are said to constitute a 'spheroidal epithelium.' The most important example of it is presented by the urinary passages, which it lines from the pelvis of the kidneys to the inner orifice of the urethra; but it is also found in the excretory ducts of the mammary, perspiratory, and some other glands; and presents itself also as the characteristic form in many situations, in which the secreting process is most actively going on. This form may pass by insensible gradations into either of the other two.

231. Both the two principal forms of Epithelial cells are frequently observed to be fringed at their free margins with delicate filaments, which are termed *Cilia;* and these, although of extreme minuteness, are organs of great importance in the animal economy, through the extraordinary motor power with which they are endowed. The form of the ciliary filaments is usually a little flattened, and tapering gradually from the base to the point. Their size is extremely variable; the largest that have been observed being about 1-500th of an inch in length, and the smallest about 1-13,000th. When in motion, each filament appears to bend from its root to its point, returning again to its original state, like the stalks of corn when depressed by the wind; and when a number are affected in succession with this motion, the appearance of progressive waves following one another is produced, as when a corn-field is agitated by frequent gusts. When the ciliary movement is taking place in full activity, however, nothing whatever can be distinguished, but the whirl of particles in the surrounding fluid; and it is only when the rate of movement slackens that the shape and size of the cilia, and the manner in which their stroke is made, can be clearly seen. The motion of the cilia is not only quite

Fig. 21.


Vibratile or ciliated Epithelium; *a*, nucleated cells, resting on their smaller extremities; *b*, cilia.

independent (in all the higher animals at least) of the will of the animal, but is also independent even of the life of the rest of the body; being seen after the death of the animal, and proceeding with perfect regularity in parts separated from the body. Thus isolated epithelium-cells have been seen to swim about actively in water, by the agency of their cilia, for some hours after they have been detached from the mucous surface of the nose; the ciliary movement has been seen *fifteen days* after death in the body of a Tortoise, in which putrefaction was far advanced; and even in Man, according to the recent observations of M. Gosselin,* it may be observed on the mucous lining of the trachea for as long as *seven days* after death.—The purpose of this Ciliary movement is obviously to propel fluids over the surface on which it takes place; and it is consequently limited, in all save aquatic animals, to certain internal surfaces of the body, and takes place in the direction of the outlets, towards which it aids in propelling the various products of secretion. A layer of ciliated epithelium, of the tesselated form, has been affirmed by Purkinje and Valentin to exist upon the delicate pia mater which lines the cerebral cavities, not even excepting the infundibulum and the aqueduct of Sylvius; but from the recent observations of Dittrich and Gerlach upon decapitated criminals, it is doubtful if this movement takes place in the Human adult, the previously-cited results having been afforded by embryoes and by the lower animals.† A cylindrical epithelium furnished with cilia is found lining the nasal cavities (except over the olfactory region), the frontal sinuses, the maxillary antra, the lachrymal ducts and sac, the posterior surface of the velum pendulum palati, and fauces, the Eustachian tube, the larynx, trachea, and bronchi to their finest divisions, where it passes into the tesselated form, the upper portion of the vagina, the uterus, and the Fallopian tubes. The function of the cilia in all these cases appears to be the same; that of propelling the secretions, which would otherwise accumulate on these membranes, towards the exterior orifices, whence they may be carried off.

232. Of the agency to which the Ciliary movement is immediately due, it is difficult to give any precise account. Although the fact cannot be substantiated in the case of the minute cilia of the epithelium-cells of Man, yet a careful examination of the much larger cilia of some of the lower animals, especially aquatic Mollusks and Animalcules, suggests the idea that they are veritable prolongations of the cells, of which they have usually been regarded as mere appurtenances;‡ and that their rhythmical movement is to be regarded, no less than the changes of shape in entire cells, as a manifestation of cell-force (§ 110). It certainly depends upon the continued vitality of the cell, and is affected by agencies which tend to increase or to repress its vigour. And the fact already mentioned (§ 113) as to the reciprocity of ciliary movement and secretory action, is a strong indication that both proceed from the same dynamical source.

* "Gazette Médicale," 1851, No. 26. These observations were made at the Ecole Pratique, on the body of a decapitated criminal.

† See the "Präger Vierteljahrschrift" for 1851, cited in the "Edinb. Monthly Journ.," Jan. 1852, p. 82.

‡ This is certainly the case with regard to the long filamentous processes of many (so-called) Animalcules, which only differ from cilia in being of much larger size, and in not being multiple; between the two forms, however, there are many intermediate gradations, so that the similarity of their nature can scarcely be doubted.

It has been maintained by some, that the action of the cilia is muscular; but these filaments are usually too small to contain even the minutest fibrillæ of true muscular tissue; and we can scarcely but regard them as organs *sui generis*, which do not owe their peculiar endowments to any other.

233. The Epithelium of most parts of the surface of the Mucous Membranes appears to be frequently exuviated and renewed; in fact, in most cases in which it has a true secretory action, that action is completed by the detachment of the epithelial cells, after they have developed themselves at the expense of the peculiar matter which they have drawn from the blood; and preparation is soon made by a new growth for a repetition of the secreting process. No very positive account can be given, of the mode in which the epithelial cells originate; but there are appearances which indicate that it is not always the same. Thus in most of the cases in which a spheroidal epithelium presents itself as the active instrument of secretion (as, for instance, on the villous prominences of the synovial membranes, § 227), its cells are observed to be in different stages of development, and they are embedded in a granular blastema, in which it appears probable that they may originate *de novo*, after the manner already described (§ 106). But in many other cases, the epithelial cells covering an extensive tract are so very similar to one another in form, size, and grade of development (Fig. 20), that it is obvious that they must have been all produced, and all brought to a readiness for exuviation, at the same time; and it not unfrequently happens, more especially in the case of the cylinder epithelium of the intestinal villi, that, when detached from the basement membrane, the cells are still found to be adherent to each other, and to carry upon their broad free surface a thin membranous pellicle (*a*, *a*), which may be made more distinct by the action of water. Here it would seem more likely that the cells are developed in the very substance of the basement-membrane, perhaps from 'germinal spots' contained in itself, as suggested by Prof. Goodsir (§ 119); and that, in the course of their enlargement, they carry before them the outer layer of the basement-membrane beneath which they originated.—So, again, in the case of the secreting follicles, there are indications that the cells they contain are sometimes developed in the midst of a blastema exuded from their walls; whilst in other instances the origin of the cells seems traceable to a 'germinal spot' at the cæcal extremity of the follicle, or to several such spots dispersed over its sides. Upon the whole of this subject—the conditions under which the exuviation of the Epithelium occurs, the frequency with which it usually takes place, and the mode in which its renewal is effected—much still remains to be learned.

234. We have now to consider, in somewhat more detail, certain appendages to the Mucous membranes, which are found in connection with particular parts of them; and which may be considered as special developments of their ordinary elements.—Thus in the mouth, and especially on the tongue, we meet with numerous slight elevations or *papillæ*, some of which are very minute and simple, whilst others are larger and more complex, being cleft (as it were) into secondary papillæ. The intimate structure of these is by no means uniform; and the purposes which they answer are probably very diverse. Thus, whilst the 'fungiform'

papillæ have a soft epithelial covering, and are copiously supplied with blood-vessels and nerves, so as to serve for the reception of gustative impressions, the 'conical' are furnished with a firm horny epithelial investment, sometimes prolonged into fine filaments, and are less copiously supplied with nerves and blood-vessels, their function being probably the purely mechanical one of assisting in the abrasion and comminution of the food. It is curious that the fungiform papillæ contain striated muscular fibres, which pass up to them from the muscular substance of the tongue, a fact first announced in regard to the Frog by Dr. Edmund Waller;* and that they undergo a kind of erection from the turgescence of their vessels, when sapid substances are brought into contact with them.—In the œsophagus and stomach, we find the mucous membrane usually lying in *rugæ* or wrinkles, which are disposed with some regularity; these, however, are simple folds, into which the membrane is thrown by the contraction of the muscular coats of these organs, and are obliterated by distention of the latter. A permanent series of folds however, which can only be obliterated by dividing the outer coats of the canal, are found in the small intestine, where they are known as the 'valvulæ conniventes.' The chief use of these appears to be to increase the absorbent surface.—The mucous surface of the small intestine, from the pyloric orifice to the cæcum, is thickly beset with *villi*, which are prolongations of the basement-membrane, having somewhat the form of the finger of a glove, copiously furnished with blood-vessels from the subjacent surface (Fig. 22), and also containing lacteal tubules in their interior. In form they are sometimes nearly cylindrical, sometimes rather conical, and not unfrequently become flattened and extended at the base, so that two or more coalesce. Their length varies from 1-4th to 1-3rd of a line, or even more; and the broad flattened kinds are about 1-6th or 1-8th of a line in breadth. In the upper part of the small intestine, where they are most numerous, it has been calculated by Krause that there are not less than from 50 to 90 in a square line; and in the lower part, from 40 to 70 in the same space. An approach to the villous structure is presented by the portion of the mucous membrane of the stomach, in the neighbourhood of the pylorus; but the prominences which are here found between the orifices of the gastric follicles, are much smaller than the true villi of the intestine, and contain no lacteal vessels.

Fig. 22.

Villi of the Human Intestine, with their capillary plexus injected.

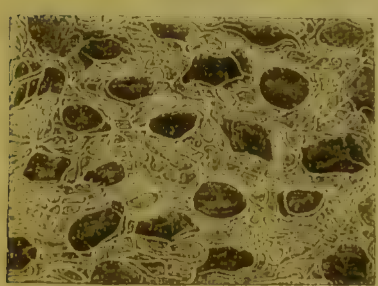
There can be no doubt that the proper intestinal villi are the chief instruments of absorption, by means both of their blood-vessels, which take up soluble matters by simple imbibition, and of their lacteals, which absorb certain special products of the digestive operation. In the selection of these, it will be hereafter shown that the epithelial cells of the villi are the instruments chiefly concerned; these filling themselves with the

* "Philosophical Transactions," 1849, p. 143.

materials of chyle from the contents of the alimentary canal (Fig. 100), and then delivering them up to be absorbed by the lacteals beneath (CHAP. VIII. SECT. 1).

235. The inversion of the mucous surface into *follicles*, gives to it a character precisely the reverse of the preceding, both as regards structure and function. These follicles, in their most elementary form, may be regarded as originating in a recession of the basement-membrane (as if the finger of a glove were pushed back into the interior of the palm); they are nearly of a cylindrical shape, their orifices opening upon the free surfaces of the mucous membrane in the interspaces of the vascular net-work (Fig. 23), while their cæcal extremities, which are sometimes simply-rounded, sometimes loculated, abut against the submucous areolar tissue. Such follicles present themselves along the whole extent of the gastro-intestinal mucous membrane; but although very similar in their appearance in different parts of its length, their secretion is probably very different. In the stomach they are known as the 'gastric follicles,' and the digestive solvent is prepared and poured forth by them. Along the course of the intestine, on the other hand, they are known as the 'follicles of Lieberkuhn;' and it is doubtful whether they form any other secretion than that of protective mucus. Such follicles are not known to exist in any other than the open state; and they seem to have a permanent character, continually discharging new broods of epithelial cells. The secreting action of these follicles may be best observed in those of the stomach; which, during the intervals of the digestive process, become turgid with cells, that accumulate in such quantity, as to give to the tubes a sacculated appearance which they do not possess when empty; within the principal cells, smaller ones are frequently observable, and even a second brood may be sometimes seen in the interior of the latter;* and when digestion is going on, these cells are poured out in large numbers on the surface of the mucous membrane, where they undergo a kind of deliquescence by the imbibition of water, and form the substance, indefinitely termed mucus, which probably contains the 'ferment' that is the essential accompaniment of the acid solvent in the process of gastric digestion.—Besides these follicles, however, which are by no means peculiar to the lining of the alimentary canal, the gastro-intestinal mucous membrane contains numerous other simple glandulæ, which afford links of transition towards those more complicated forms of the glandular apparatus that are less intimately connected with it. Reserving a more particular description of these for a future opportunity (CHAPS. VII. and XIII.), we shall here only notice the points that bear upon the essential nature of Glands in general. Various parts of the mucous membrane of the stomach, and of the large intestine, are studded at intervals with shallow pits or follicles, about 1-20th of an inch in diameter; which, according to the observations of Dr. A. Thomson (loc. cit.), have the form

FIG. 23.

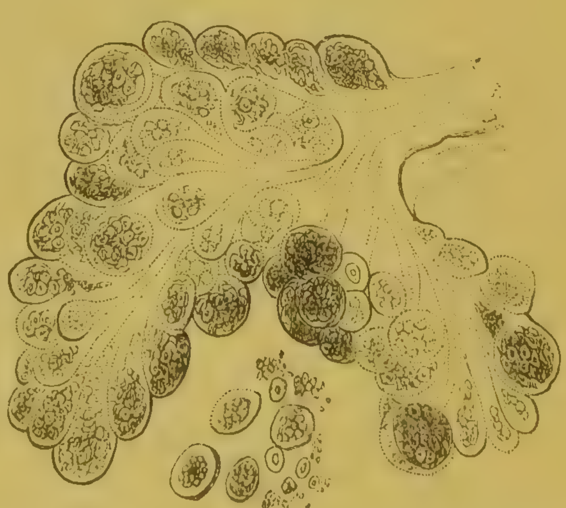


Distribution of Capillaries around follicles of Mucous Membrane.

* Dr. Allen Thomson, in Goodsir's "Annals of Anatomy and Physiology," No. I. p. 36.

of closed vesicles during fœtal life and early infancy, but gradually open, so that their cavities become continuous with the free surface of the mucous membrane, the columnar epithelium of which extends itself into them; and they remain in that condition during the rest of life. What their distinctive attribute may be, however, has not been made out.—The mucous lining of the small intestine is beset at intervals with elevated patches, which are known under the name of the 'agminated glands of Peyer.' These are formed by the aggregation of originally-closed vesicles of a somewhat lenticular shape, which lie just beneath the mucous membrane, their own walls being closely incorporated, at the deeper side, with the subjacent filamentous tissue; and they are filled with cells and granular particles in various stages of development. It seems probable from the observations of Profs. Krause and Allen Thomson, that these vesicles are continually opening and discharging their contents upon the mucous surface; each, when it has completely emptied itself, becoming atrophied, and being replaced by another. These, also, are apparently to be looked upon as secreting organs; but they can scarcely be considered in any other light than as parent-cells, developed in the substance of the tissues, quite independently of the mucous surface, with which they only become connected for the purpose of giving exit to their contents. Such, it is probable, is the original state of the elements of most of the more complex glandular structures; the essential part of them seeming to consist of a collection of glandular vesicles, which are originally closed (a condition that is retained in the thyroid throughout life), but which afterwards come into connection with the mucous or cutaneous surface whereon they discharge their secretion, by an extension of an offset from the latter, that constitutes the ramifying ducts on which they open. A simple type of this more complex glandular apparatus is presented to us in those small bodies peculiar to the duodenum, which are known as 'Brunner's glands' (Fig. 24). The terminal vesicles of these racemose clusters are loaded with cells formed in their interior, the aspect and mode of production of which are quite different from those of an epithelium. This will be better understood from the succeeding figure (Fig. 25), which represents one of the terminal cæca of the liver of the Crab; this is seen to be crowded with cells, which not only line its internal surface, but fill its cavity; and the cells are observed to originate in the midst of an indistinct granular matter that occupies the deeper portion of the follicle, increasing in size and completeness as they are pushed towards its outlet by newer growths beneath. In most glands, an unlimited production of cells appears to take place continuously within the same follicles; the

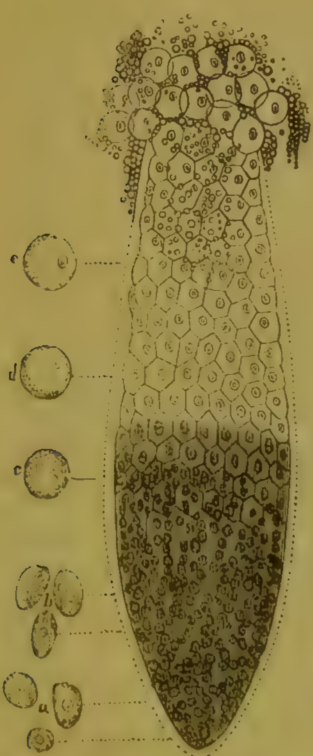
Fig. 24.



Portion of one of *Brunner's Glands*, from the Human Duodenum. Magnified 65 diameters.

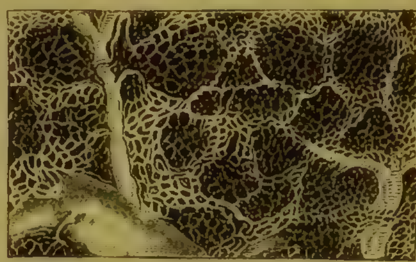
cases in which the follicles shrivel and dwindle away, when they have once opened themselves and discharged their contents, being comparatively few. —All glandular structures require a copious supply of blood, to furnish the materials of the secretion which they eliminate; and this is afforded by a minute capillary network, which closely surrounds the follicles or vesicles, but which never penetrates their interior (Fig. 26).

Fig. 25.




One of the hepatic cæca of *Astacus affinis* (Cray fish), highly magnified, showing the progress of development of the secreting cells from the blind extremity to the mouth of the follicle; specimens of these, in their successive stages, are shown separately at *a*, *b*, *c*, *d*, *e*.

Fig. 26.



Capillary Network around the follicles of Parotid Gland.

236. *The Skin.*—Like the Mucous Membranes with which it is continuous at the nose, mouth, anus, and the other orifices of the canals which these line, the Skin may be considered as composed of three elements; namely, the complex fibrous tissue, which, with blood-vessels, lymphatics, and nerves, makes up the *Cutis vera*, or *Corium;* a layer of *Basement-membrane* investing this, and an epithelial investment of peculiar thickness and tenacity, which is known as the *Epidermis* or 'cuticle.'—The substance of the Corium is principally composed of White fibrous tissue, which is arranged in a reticular manner; the texture being very fine and close near the surface, but more open in its deeper layers, where its areolæ become occupied with clumps of fat-cells, and where it passes, without any distinct line of separation, into that of the subcutaneous Areolar tissue. With this white fibrous tissue, a small proportion of yellow or elastic fibres is usually intermixed; and this proportion is greatly increased in those parts of the skin which are subject to occasional distention, and especially in the integument surrounding the joints. The Cutis, however, not only possesses elasticity; but is also endowed with vital contractility, which is peculiarly manifest in particular parts, especially under the influence of cold or of mental emotion; producing the corrugation of the integuments of the scrotum, and that peculiar condition of the general surface which is known as the 'cutis anserina.' The real nature of its contractile element, however, has only been recently discovered by Prof. Kölliker; who has found it to consist of 'smooth' or non-striated muscular fibre-cells (Fig. 79), which are united into fasciculi, and dispersed among the other elements of the cutaneous substance. They are especially abundant in the deeper part

of the cutis of the scrotum, where they form a reticular layer which is known as the 'tunica dartos;' and also in the skin of the penis and perineum, as well as in the nipple and areola. In other parts of the integument, they are especially connected with the hair-follicles; and where these are wanting, as on the palms of the hands and soles of the feet, there are no muscular fibre-cells. In the production of the 'cutis anserina,' which may be artificially induced by the application of the magneto-electric apparatus, these fibres cause the protrusion of the hair-follicles, while they retract and depress the intermediate cutaneous surface.*

237. The external surface of the Corium is elevated in many parts into papillæ or ridges, which, though representing the villi of mucous membranes, have an entirely different office; their special function being usually to receive tactile impressions through the medium of the nerves with which they are furnished, their size and number being proportional to the acuteness of the sensibility possessed by different parts of the surface. In general, the papillæ are simple conical projections, the length of which is from about 1-33rd to 1-22nd of a line; but on the palm, sole, and nipple, they are mostly compound (that is, they have several distinct summits), and measure from 1-20 to 1-10th of a line in length. In these last situations, they are set very closely together in curvilinear ridges, which are marked at tolerably regular intervals by short transverse furrows, into each of which the orifice of one of the sweat-glands discharges itself. On some parts of the surface, however, the papillæ are altogether wanting; and in the matrix of the nail, where they are as large and numerous as on the palms of the hands, they serve an entirely different purpose, that of affording a more extended surface for the production of epidermic cells. The basement-membrane may be tolerably well made out by the definite boundary which it affords to the components of the papillæ; but it is not distinguishable in a like degree on the general surface of the Corium; and its presence there can only be inferred from analogy, and from the existence of a fine film in that situation in the embryo.—The surface of the Corium likewise presents numerous depressions, which are sometimes mere follicles, but sometimes tubuli of considerable length. All these depressions are lined by cells, which are continuous with those of the Epidermis; but the function of these cells is very different in the several varieties of the follicular organs. Thus, in the Hair-follicles, we find them undergoing transformation into the substance of the hair, which is chemically identical with that of the Epidermis itself; in the Sebaceous follicles, on the other hand, they draw fatty matter from the blood, and set free this upon the surface of the skin; in the Cerumen-glands, they elaborate a waxy matter, which they discharge on the integument lining the meatus of the ear; in the Sudoriparous glandulæ, with which nearly every part of the surface is furnished, they are the instruments of drawing-off a large amount of watery fluid, which holds in solution a small proportion of effete organic compounds; and in the peculiar large sudoriparous glandulæ of the axillæ, they further seem to eliminate from the blood the peculiar Odorous

* See Prof. Kölliker's Memoir on the 'Smooth Muscular Fibre,' in "Kölliker and Siebold's Zeitschrift," 1849; and his "Mikroskopische Anatomie," band ii. pp. 13, 14.

secretion which is characteristic of that part.* The Hair-follicles will be presently described in connection with the Epidermis (§ 246); but a short account of the structure and development of the other cutaneous glandulæ will here be given, as further elucidating the nature of the glands in general, and as connected with the special functions of the Skin.

238. The *Sebaceous* glandulæ are for the most part found in connection with the Hair-follicles, and pour their secretion into the hair-canals near their orifices (Fig. 27, B). They are usually composed of clusters of secreting sacculi, lined with epithelium-cells, which, being filled with fatty matter, resemble the cells of adipose tissue; the number of these sacculi generally varies from four or five to twenty, but in rare cases it is reduced to three, two, or even one. The size of these glandulæ, and the number which open into the same hair-follicle, bear no proportion to the size of the hair; but are rather related to the necessity which may exist, on the several parts of the surface, for their lubrifying secretion. Some of the largest of them are found in connection with the fine downy hairs of the nose and of other parts of the face; and their orifices being often obstructed by particles of foreign matter, they become distended with their adipose secretion, and not unfrequently afford the nidus to a curious parasite, which seems to belong to the Arachnidan class, and is not known to exist elsewhere.†—The development of the Sebaceous glandulæ, which has been recently made the subject of careful study by Prof. Kölliker,‡ commences at about the sixth month of fœtal life, in a sort of excrescence of the

Fig. 27.


Cutaneous Glandulæ of external meatus auditorius:—A, section of the Cutis, magnified three diameters; *b*, *b*, hairs; *c*, *c*, superficial sebaceous glands; *a*, *a*, larger and deeper-seated glands, by which the cerumen is secreted.—B, a Hair, perforating the epidermis at *c*; *a*, *a*, sebaceous glands, with their excretory ducts *b*, *b*; *d*, base of the hair, in its double follicle *e*, *e*.—C, cerumen-gland, formed by the contorted tube, *a*, *a*, of the excretory duct, *b*; *c*, vascular trunk and ramifications. The last two figures highly magnified.

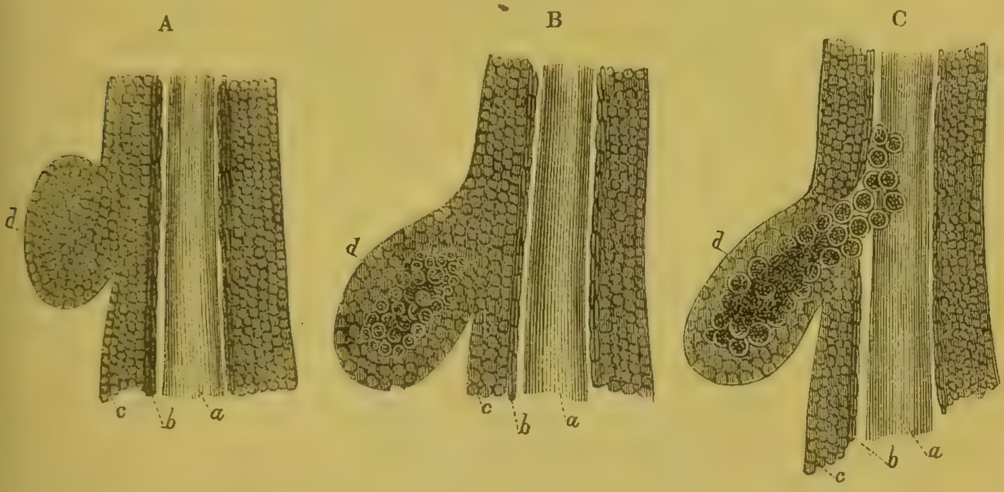
* See Prof. Horner in the "Amer. Journ. of Med. Sci.," Jan. 1846; and M. Robin in the "Ann. des Sci. Nat.," 3ième ser., Zool., tom. iii. p. 380.

† See Dr. Gustav. Simon, in "Müller's Archiv.," 1842; Mr. Erasmus Wilson, in "Philos. Transact.," 1844, and "Healthy Skin," 3rd edit. pp. 50–53; and Prof. Owen's "Lectures on Comparative Anatomy," vol. i. p. 252.

‡ "Mikroskopische Anatomie," band ii. pp. 192–196.

cellular lining (root-sheath) of the hair-follicle (Fig. 28, A, *d*), which is, in fact, a continuation of the deeper portion of the Epidermis (§ 241). Each of these little processes, which is at first solid, soon assumes somewhat of a flask-shape, through the narrowing of its neck (B, *d*); but as its

FIG. 28.




Development of the *Sebaceous Glands*, in connection with the hair-follicles, from a Fœtus of six months:—A, incipient development of the glandular papilla, from the cells of the outer root-sheath;—B, the same, having assumed the flask-shape, and showing the first appearance of fat-cells in its interior;—C, extension of the formation of fat-cells through the pedicle, and their expulsion into the hair-canal:—*a*, hair; *b*, inner root-sheath; *c*, outer root-sheath; *d*, incipient sebaceous glands.

development advances, a group of cells containing fat-particles appears in its centre, and gradually extends itself along the axis of the pedicle, until it penetrates through the root-sheath (C); and the fat-cells thus escape into the cavity of the hair-follicle, and constitute the first secretion of the sebaceous gland. They are soon succeeded by others of the same kind, and the little gland is established in its office; additional sacculi and recesses being subsequently formed by the budding-out of its cellular lining, as the first was produced by out-growth from the root-sheath. The purpose of the Sebaceous secretion is to keep the Skin from being dried and cracked by the action of heat and of air, and thus to maintain its flexibility; and also to diminish the friction between those parts of the surface which move one over another. Hence we find it especially abundant on the integument of the face and head, which is necessarily more exposed than that of any other part to the sun and atmosphere; and also in the neighbourhood of the joints. Its amount is peculiarly great in the races which are formed to inhabit warm climates; and it is probable that habitual exposure of the surface generally would considerably augment the quantity of unctuous matter poured forth for its lubrication.—The *Sudoriparous* glandulæ essentially consist of long convoluted tubes (Figs. 27, C, and 125, *a*, *a*), which, however, are rarely single, but are multiplied by repeated dichotomous subdivision, sometimes also giving off short cæcal processes before their termination. These are seated rather beneath the Corium, in the midst of the subcutaneous adipose tissue, than in the substance of the skin itself. All the tubuli of each gland unite so as to form but one duct; and this passes upwards through the Cutis and Cuticle, in a somewhat corkscrew-like manner, to open upon the surface of the latter, which it

usually reaches obliquely, so that the outer layer of the Epidermis forms a sort of little valve, which is lifted by the secreted fluid as it issues forth. The Ceruminous glandulæ of the meatus auditorius, and the Odoriferous glandulæ of the axilla, are mere local varieties of the ordinary sudoriparous; corresponding with them in structure, but differing in the character of their secretion. The development of all these glandulæ seems, according to the observations of Prof. Kölliker (Op. cit. pp. 167-172), to commence very much after the fashion of that of the hair-follicles (§ 247); namely, by a knob-like projection of the deeper layer of the Epidermis, which is received into a hollow of the Cutis. This gradually elongates, so as to penetrate deeper and deeper into the skin; and a cavity is formed along its axis, which, though at first destitute of an outlet, gradually reaches to the surface; whilst at the same time, the deeper portion becomes coiled upon itself, and the number of tubes increases by out-growth from the one first formed. The secretory action of these glandulæ has reference rather to the wants of the economy in general, than to the special functions of the Skin; and it will, therefore, be more appropriately considered hereafter (CHAP. XII. SECT. 4).

239. The Cutis is very copiously supplied with Blood-vessels, which distribute blood, through capillary plexuses of great minuteness, to the sweat-glands, hair-follicles, and fat-clumps of its deeper portion, and then form a dense network near its surface, from which looped branches are sent up into the papillæ, the distribution of these last being nearly the same whether the papillæ are endowed with tactile sensibility, or are subservient to the formation of the nail-substance.* The Lymphatics of the skin, also, are very numerous, and form minute plexuses near the surface. A copious supply of Nerves, too, is sent to the skin; especially to such parts of it as are thickly set with tactile papillæ; these form a minute plexus through the whole substance of the skin, which becomes finer and closer as it approaches the surface, its branches at length coming to contain but one or two fibres each; and from the most superficial portion of the plexus, fibres pass up into the papillæ, which there terminate in loops.†—Thus we see that the Vascularity of the Skin has purposes very different from those which it answers in the Mucous membranes; a large part of the blood which this tissue receives, being destined to afford to the nerves of Touch the means of their activity; and one chief office of the remainder, being to supply the material for the production of the protective Epidermis and its appendages. It is only in the excretory action of the Sudoriparous glandulæ, and in the slight absorptive power which the Skin possesses, that we trace any functional relation to the great Mucous-membrane system. The Skin, in fact, ministers almost as exclusively to the operations of Animal life, as do the Mucous Membranes to that of Organic life.—The *nutrition* of the various textures composing

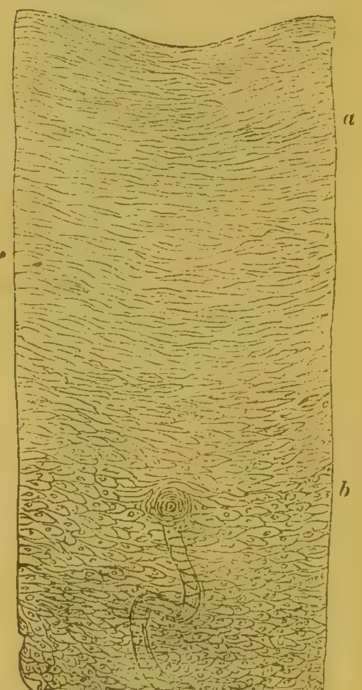
* It is a curious circumstance that the under surface of the Dog's foot has a set of large composite papillæ, that are concerned in the formation of its thick cuticular investment; which, so far as the arrangement of their vessels is concerned, closely resemble those of the fungiform papillæ of the tongue.

† The existence of this mode of termination of the Nerve-fibres, first admitted on the authority of Gerber, and confirmed by Purkinje and Krause, but looked-for in vain by other equally competent observers, has been lately established by Prof. Kölliker ("Mikroskopische Anatomie," band ii. pp. 24–31), who states that it may be traced with comparative ease, if the skin be first steeped in a weak solution of caustic soda.

he Skin may be considered to take place with an activity proportionate ) their several requirements; thus, whilst the various glandular organs, ie hair-follicles, the nervous papillæ, and the muscular fibres, are con- nually drawing new elements from the blood, it is probable that the brous tissues which constitute the essential basis of this texture are ot more rapidly renewed than they are elsewhere (§ 220). The *rege- eration* of the Skin, after the loss of a portion of it by disease or injury, . effected with almost entire completeness. The new tissue is at first iore dense and less vascular than the old; but it soon gives such idications of sensibility as make it evident that nerve-fibres must be ery early formed in its substance; and the epidermis is normally deve- iped from its surface. It has been asserted that no tactile papillæ are ver formed upon regenerated skin, and that in the Negro the pig- ient-cells are not reproduced, so that the cicatrix remains light. Neither f these statements, however, is correct; though it is quite true that ome time elapses before the pigment-cells of the Negro epidermis are ormed again in their usual amount. It is not yet certain that the air-follicles and sudoriparous glands are formed in regenerated skin.

. 240. The *Epidermis* usually forms a thin semi-transparent pellicle, in ose apposition with the surface of the Cutis, filling up the spaces between s papillæ, so as to obliterate its inequalities, id investing the whole with a stratum of early uniform thickness (Figs. 30, 31); so iat whilst its under side is pitted for the ception of the cutaneous papillæ, its outer · free surface is nearly level. In some parts, owever, the Epidermis is enormously in- eased in thickness; such being particularly ie case with those spots which are subjected continual pressure or friction, such as the ilms of the hands and the soles of the feet. s substance consists of a series of flattened ale-like cells, which, when first formed, are heroidal, but which gradually dry up, their iclei also at last disappearing. These form veral layers, of which the deeper can be seen ry distinctly to possess the cellular charac- r, whilst the external layers are scaly; and tween these, all stages of transformation ay be traced (Fig. 29),—the outer layers ing continually thrown off by desquama- on, whilst new ones are as constantly being rmed below. The outer and inner portions the Epidermis, however, present a marked fference in character, which is made still ore apparent by the use of reagents; for hilst the former (Fig. 30, *a*) is a comparatively m horny membrane, which is not affected ther by acetic acid, or by a moderately rong solution of potash, the latter is soft and deficient in tenacity, and dissolved (or at least reduced to an apparently structureless condition)

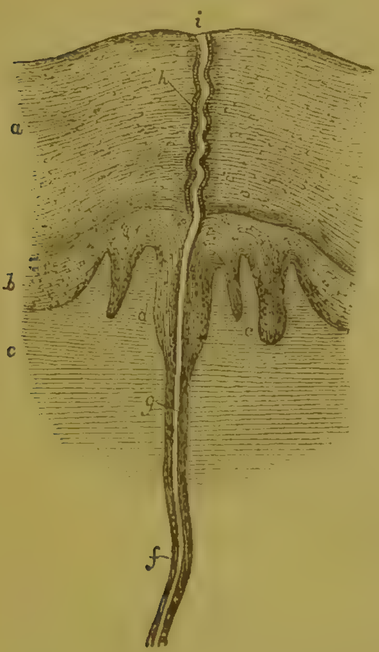
FIG. 29.




Vertical section of Epidermis, from palm of the hand:—*a*, outer portion, composed of flattened scales; *b*, inner portion, consisting of nucleated cells; *c*, tortuous perspiratory tube, cut across by the section higher up. Magnified 155 diameters.

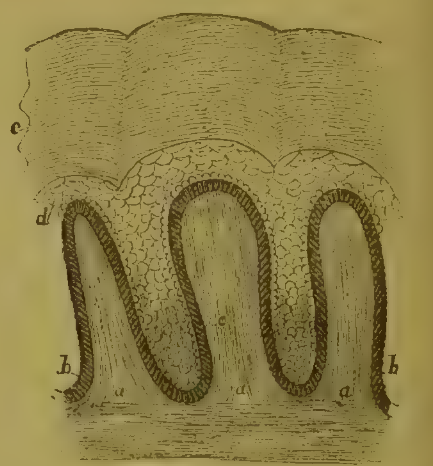
when treated with either of these liquids. They are further distinguished in the operation of vesicating agents; for the fluid which they cause to be effused from the vessels of the cutis, raises little else than the outer

Fig. 30.




Vertical section of the *Skin* of the Thumb, showing the Epidermis and outer layer of the Corium; treated with acetic acid:—*a*, horny layer of Epidermis; *b*, mucous layer; *c*, cutis vera; *d*, single papilla; *e*, composite papilla; *f*, epithelium of the perspiratory duct, continuous with the mucous layer of the epidermis; *g*, canal of the same through the cutis; *h*, its passage through the horny portion; *i*, perspiratory pore.

Fig. 31.




Vertical section of the *Skin* of the Thigh of a Negro, more highly magnified:—*a*, *a*, *a*, three papillæ of the Cutis; *b*, *b*, deepest layer of columnar cells, deeply coloured; *c*, spheroidal cells filling up the spaces between the papillæ, still dark; *d*, upper more faintly coloured portion of the mucous layer of the epidermis; *e*, horny layer, with scarcely any perceptible colour.

horny layer of the cuticle, as it passes readily through the softer tissue beneath. The internal layer of the cuticle (Fig. 30, *b*) was formerly supposed to be a distinct structure, and was termed the *rete mucosum*, or *stratum Malpighii;* it is now well known, however, to be chiefly formed by the younger portion of the epidermis, whose cells are not yet consolidated by the formation of horny matter in their interior. In immediate contact with the basement-membrane of the cutaneous papillæ, however, there is usually found a layer of elongated cells, resembling those of columnar epithelium, arranged perpendicularly to the surface of the corium (Fig. 31, *b*, *b*); sometimes two, or even three strata of such cells present themselves. They are obviously different in character from those of the superjacent layers, for they resist the action of a solution of potash that is strong enough to dissolve the latter, though they are themselves dissolved by a stronger solution, which does not act upon the horny layer of the cuticle;* and it seems not improbable that these permanently retain their place, and are not successively carried to the surface by the formation of new layers beneath, as are the spheroidal cells (Fig. 31, *c*, *d*) which lie upon them. In what way these spheroidal cells originate, has not yet been ascertained. It has been generally supposed that they are formed upon free nuclei in the midst of a blastema that intervenes

* See Messrs. Todd and Bowman's "Physiological Anatomy," vol. i. p. 414.

beneath the cutis and the 'stratum Malpighii;' but the researches of Prof. Kölliker tend to negative this idea, and to render it probable that they multiply by endogenous production.* In whatever mode they are generated, the nutriment which they require for their growth and development must be drawn from the vessels of the Cutis, through the medium of the basement-membrane; since, however thick may be the substance of the Epidermis, it is never penetrated by vessels. The Epidermis is pierced by the excretory ducts of the sebaceous and sweat-glands, those of the latter passing through it with a somewhat corkscrew-like turn (Fig. 30, *g*, *i*), and both being lined with an epithelium (*f*) which is continuous with that of the mucous layer of the cuticle. It is also pierced by the Hairs, with whose substance (as we shall presently see) it has a like relation of continuity through their follicles. The horny layer has the same chemical composition with Nails, Hoofs, Horns, Hair, and Wool; the formula of all of them being 48 C, 39 H, 7 N, 17 O.

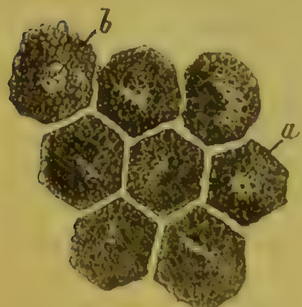
241. The Epidermis covers the whole exterior of the body, not excepting the Cornea and the Conjunctival membrane, where, however, it has more the character of an Epithelium; this continuity is well seen in the cast skin or *slough* of the Snake, in which the covering of the front of the eye is found to be as perfectly exuviated as that of any part of the surface. The Epidermis appears solely destined for the *protection* of the true Skin, from the mechanical injury and the pain occasioned by the slightest abrasion, and from the irritating influence of exposure to air and of changes of temperature: we perceive the value of this protection, when it has been accidentally destroyed. The cuticle is very speedily and completely replaced, however; the increased determination of blood to the Cutis, which is the consequence of the irritation, being favourable to the accelerated production of Epidermic cells from its surface. It is probable that pressure and friction may act in the same manner; for although the peculiar thickness of the Epidermis on the palms and soles is well marked even in the fœtus (in obvious preparation for the future requirements of these parts), yet, when parts of the surface on which the Cuticle was originally thin, are habitually exposed to pressure or friction, its substance undergoes a great augmentation.—The Cuticle is completely exuviated at the close of some Exanthematous diseases, especially Scarlatina; and we are probably to regard this as one of the modes in which morbific matter is eliminated from the system (§ 215). It usually 'desquamates' in minute shreds, or peels off in larger patches; but sometimes the entire cuticle of the hand or foot, even with the nails attached, comes off at once, like a glove drawn from the hand. A new Epidermis is always pre-formed beneath that which is thus shed; as in the normal exuviation of the lower animals.

242. Mingled with the ordinary Epidermic cells, we find some which secrete Colouring-matter; these are termed *Pigment-cells.* They are not readily distinguishable in the Epidermis of the fair races of mankind, except in certain parts, such as the areola around the nipple, and in freckles, nævi, &c. But they are very obvious, on account of their dark hue, in the newer layers of the Epidermis of the Negro and other coloured races; and, like true Epidermic cells, they dry up, and become flattened

* See his "Mikroskopische Anatomie," band ii. §§ 14–22.

scales, in passing towards the surface, thus constantly remaining dispersed through its substance, and giving it a dark tint when it is separated and held up to the light. The colour is more apparent in the cells of the 'stratum Malpighii,' than it is in those of the horny layer; and it is particularly deep in the stratum of columnar cells that lies in immediate contact with the surface of the Cutis (Fig. 31, *b*, *b*).—In all races of men, however, we find the most remarkable development of Pigment-cells on the inner surface of the Choroid coat of the eye; where they form several layers, known as the *Pigmentum nigrum.* When examined separately, these are found to have a polygonal form, and to have a distinct nucleus in their interior (Fig. 32). The black colour is given by the accumulation, within the cell, of a number of flat, rounded or oval granules, measuring about 1-20,000th of an inch in diameter, and a quarter as much in thickness; these, when separately viewed, are observed to be transparent, not black and opaque; and they exhibit an active movement when set free from the cell, and even whilst enclosed within it.—The Pigment-cells are not always of a simple rounded or polygonal form; they sometimes present remarkable stellate prolongations, such as those seen in the skin of the Frog (Fig. 66); and occasionally, the cells being more nearly approximated to each other, these prolongations communicate, so as to form a kind of network.—The Chemical nature of the Black pigment has not yet been distinctly ascertained; it has been shown, however, to have a very close relation with that of the Cuttle-fish ink, or Sepia, which derives its colour from the pigment-cells of the ink-bag, and to include a larger proportion of carbon than most other organic substances,—every 100 parts containing $58\frac{1}{2}$ of that element.

FIG. 32.



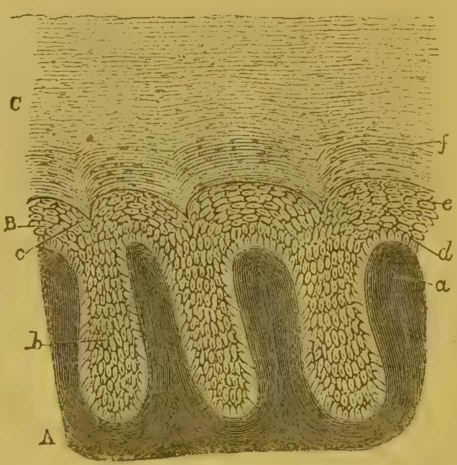

Cells from Pigmentum Nigrum:—*a*, pigmentary granules concealing the nucleus; *b*, the nucleus distinct. Magnified 410 diameters.

243. It cannot be doubted that the development of the Pigment-cells of the Skin is very much influenced by exposure to *light;* and in this respect there is a remarkable correspondence between Animals and Plants,—the coloration of the latter, as is well known, being entirely due to that agent. Thus, it is a matter of familiar experience, that the influence of light upon the skin of many individuals, causes it to become spotted with brown *freckles;* these freckles being aggregations of brown pigment-cells, which either owe their development to the stimulus of light, or are enabled by its agency to perform a decided chemical transformation, which they could not otherwise effect. In like manner, the swarthy hue, which many Europeans acquire beneath exposure to the sun in tropical climates, is due to a development of dark pigment-cells; and to this we usually find the greatest disposition in individuals or races, that are already of a somewhat dark complexion. The deep blackness of the Negro skin seems dependent upon nothing else than a similar cause, operating through successive generations (CHAP. XX.). It is well known that the new-born infants of the negro and other dark races, do not exhibit nearly the same depth of colour in their skins, as that which they present after the lapse of a few days, when light has had time to exert its

nfluence upon their surface; and further, that in those individuals who ceep themselves during life most secluded from its influence, we observe the 'ghtest hue of the epidermis. Thus among the intertropical nations, the amilies of Chiefs, which are not exposed to the sun in the same degree vith the common people, almost always present a lighter hue; and in ome of the islands of the Polynesian Archipelago, bordering on the Equator, they are not darker than the inhabitants of Southern Europe.—An occasional development of dark pigment-cells takes place during pregnancy, in some females of the fair races; thus it is very common to meet vith an extremely dark and broad areola round the nipple of pregnant vomen; and sometimes large patches of the cutaneous surface, on the ower part of the body especially, become almost as dark as the skin of a Negro.—On the other hand, individuals are occasionally seen with an ntire deficiency of pigment-cells, or at least of their proper secretion; and his not merely in the skin, but in the eye: such persons, termed Albinoes, re met with alike among the fair, and among the dark races. The bsence of colour usually shows itself also in their hair, which is almost vhite.

244. The *Nails*, like Hoof, Horn, &c., may be regarded as nothing nore than an altered form of Epidermis. When their newest and softest portions are examined, they are found to consist of nucleated cells (Fig. 33, B), resembling those of the newer layers of Epidermis; but in the nore superficial laminæ (*c*) no distinct structure can be distinguished without the assistance of reagents. When, owever, a thin slice of the nail is immersed for some little time in a dilute olution of caustic potash or soda, its issue swells up, and its component cells, hough previously flattened and compacted together, reassume their spheroidal form, and display themselves in he most beautiful manner (as was first ointed out by Donders); their nuclei, owever, are no longer distinguishable n the most superficial layers.—The Nail s produced from the surface of the orium that lies beneath it, which is olded into a groove at its root; this urface is highly vascular, and is furished with longitudinal elevated ridges (*a*), to which blood-vessels are copiusly distributed, and between which e soft inner layer of the nail dips own (*b*), like the Malpighian layer of e cuticle between the sensory papillæ.

Fig. 33.




Oblique section through the *Matrix of the Nail*:—A, Cutis of the bed of the nail;—B, mucous layer of the nail;—C, horny layer of the same, or true nail-substance; *a*, papillæ of the nail-matrix; *b*, cells of the Malpighian stratum of the nail; *c*, ridges of the true nail-substance; *d*, deepest layer of perpendicular cells of the mucous portion of the nail; *e*, upper layer of flattened cells of the same; *f*, nuclei of the true nail-substance.

he increase of the Nail in length is effected by successive additions to its ot, causing the whole nail to shift onwards; but as it moves, it receives dditional layers from the subjacent skin, which increase its thickness. ccording to the observations of M. Beau, the rate of growth in the ails of the hands is about 2-5ths of a line per week; whilst the nails of e feet require four weeks for the same increase. Thus, the length of

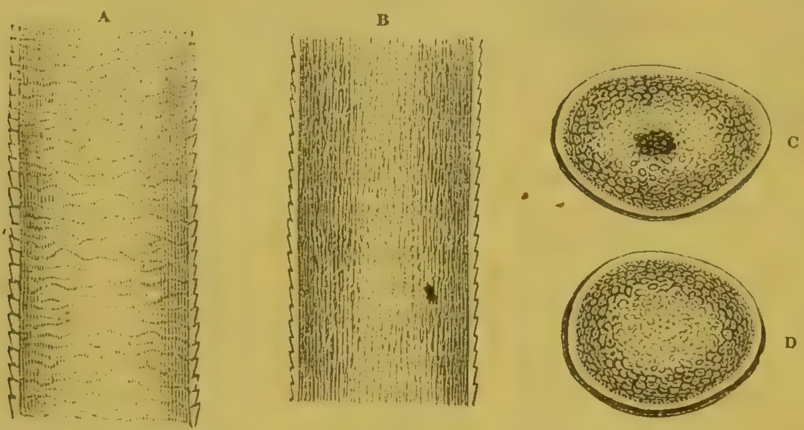
the thumb-nail (including the portion hidden from sight) being 8 lines, the period occupied in its growth would be twenty weeks; whilst the nail of the great toe, in like manner, being 9 lines in length, requires ninety-six weeks, or nearly two years. It has been further remarked by M. Beau, that although the rate of growth of the nails is not much affected by disease, the amount of nutriment they receive is usually so much diminished, that the portion of nail then produced is perceptibly thinner, and may be distinguished on the surface as a transverse groove. The breadth of this groove indicates the duration of the disease, and its depth marks the seriousness of the disturbance of the nutritive functions; whilst its distance from the root corresponds with the length of time that has elapsed since recovery.* When a Nail has been removed by violence, or has been thrown off in consequence of the formation of pus beneath it, a complete regeneration speedily takes place, provided that the matrix has received no serious injury. The Nail is continuous with the true Epidermis at every part, except at its free projecting edge, where also the continuity is maintained in the fœtus; so that it may be regarded as nothing else than an extraordinary development of epidermic structure, designed to answer certain special purposes of a purely mechanical nature.

245. The *Hair*, as originally consisting of Epidermic cells, may be properly described here; although, when fully formed, it departs widely (in Man at least) from the cellular type. It has been imagined until recently, that the Hair, in common with the other Epidermic tissues, is a mere product of secretion; its material, which is chiefly horny matter of the same composition with that of the Epidermis and its appendages, being elaborated from the surface of the pulp at its base. It is now known, however, to contain a distinctly organized structure; and to be formed by the *conversion* of a cellular mass at its root (§ 246). Although the Hairs of different animals vary considerably in the appearances they present, we may generally distinguish in them two elementary parts; a *cortical* or investing substance, of a fibrous horny texture; and a *medullary* or pith-like substance, occupying the interior. The relative proportions in which these present themselves, are subject to great variation; some hairs being almost entirely composed of the medullary substance, and others almost as exclusively of the cortical. The fullest development of both, however, is to be found in the spiny hairs of the Hedgehog, and in the quills of the Porcupine, which are but hairs on a magnified scale: their cortical substance forms a dense horny tube, to which the firmness of the structure seems chiefly due; whilst the medullary substance is composed of an aggregation of very large cells, which seem not to possess any fluid contents in the part of the hair that is completely formed, but are occupied by air only. We shall see that in the Human hair, the predominant substance is that which corresponds to the 'cortical' of that of the lower animals.—The diameter of the Hair is subject to great variation; ranging, on the heads of different individuals (according to the observations of Mr. Erasmus Wilson†), from 1-1500th to 1-140th of an inch; and from 1-1500th to 1-230th, even in the same individual. The average, however, seems to be about 1-400th of an inch, and is rather greater in the female than in the male. As a general rule, flaxen hair is the finest, and black

* See Mr. Erasmus Wilson's "Healthy Skin," 3rd edit. pp. 14-18. † Op. cit., p. 59.

the coarsest; and the most extensive range is found in light brown hair. The hair of the beard and whiskers is considerably coarser than that of the head; the former having measured 1-200th of an inch, when the average of the latter was 1-350th.—When the surface of the shaft of the Hair is carefully examined, it is seen to be covered with a layer of flattened cells or scales, arranged in an imbricated manner (Fig. 35, *c*), their edges forming delicate lines upon the surface of the hair, which are sometimes transverse, sometimes oblique, and sometimes apparently spiral (Fig. 34, A). Within this we find a cylinder of fibrous texture, which forms the principal part of the shaft of the hair; the constituent fibres of this substance, which are marked out by delicate longitudinal striæ that may be traced in vertical sections of the hair (Figs. 34, B, 35, *b*), may be separated by crushing the hair, especially after maceration in acid; and each of them consists, as has been shown by Prof. Kölliker,* of a fasciculus of flattened cells of a fusiform outline.—It has been further shown by Kölliker, that the colour of this portion of the hair is due, not only to the presence of pigmentary granules, either collected into patches, or diffused through its substance; but also to the existence of a multitude of *lacunulæ* containing air, which cause it to appear dark by transmitted and white by reflected light. Within the hollow cylinder of fibrous substance, is found a canal which is occupied by the *medullary* portion of the hair (Fig. 34, C); this consists of cells which retain more or less of the spher-

FIG. 34.




Structure of *Human Hair;*—A, external surface of the shaft, showing the transverse striæ and jagged boundary, caused by the imbrications of the scaly envelope; B, longitudinal section of the shaft, showing the fibrous character of the cortical substance, and the arrangement of the pigmentary matter; C, transverse section, showing the distinction between the transparent envelope, the cylinder of cortical substance, and the medullary centre; D, another transverse section showing deficiency of medullary substance. Magnified 310 diameters.

oidal shape (Fig. 35, *a*); and it generally presents a darker hue than the cortical substance, partly through the presence of a larger quantity of pigmentary matter in its cells, but chiefly through the greater number of air-spaces that lie amongst them. The medullary substance, however, is not unfrequently wanting; being usually deficient in the fine hairs scattered over the general surface of the body, and not being always present in the ordinary hairs of the head (D).—The chemical composition of Hair, as already stated, is precisely the same with that of the horny Epidermis (§ 240). Its colouring matter seems related to Hæmatine; it is bleached

* "Mikroskopische Anatomie," band ii. p. 105.

by Chlorine; and its hue appears to be dependent in part upon the presence of iron, which is found in larger proportion in dark than in light hair (§ 87).

246. The real nature of the different components of the Hair, and their relation to those of the Epidermis, is ascertained by examining them at its base, and by tracing their origin and connections. The hair expands at the base of the shaft into a bulbous enlargement; and this is lodged within a follicle, formed by a depression of the Cutis, and lined by a continuation of the Epidermis. The exterior of this follicle (Fig. 35) is bounded by a fibrous membrane, derived from the Corium, whose fibres are longitudinally arranged ($k$); within this is another layer, whose fibres lie transversely ($i$); and within this, again, is a structureless membrane, corresponding to the basement-membrane of other parts. The Epidermic lining of this follicle, which constitutes what is known as the 'root-sheath,' is composed of two principal layers, the one ($g$) in contact with the corium being the continuation of the stratum Malpighii, and the one nearest the hair ($e, f$) bearing a like relation to the horny layer.* At the deepest portion of the follicle, according to Prof. Kölliker, there arises a minute papillary elevation of the Corium ($l$), which occupies the centre of the hair-bulb; and over this we find a great accumulation of cells of spheroidal form, which are obviously continuous at $m$ with those of the outer root-sheath, and which are in every respect analogous to those of the Malpighian layer of the Epidermis. The envelope of imbricated scales ($c, d$), on the other hand, which the bulb as well as the shaft of the hair presents, commences deep in the follicle as a double layer of nucleated cells ($n, o$), which forms a kind of duplicature of the outer or horny stratum of the Cuticle. The fusiform cells of the fibrous portion of the shaft are continuous with those of the outer part of the hair-bulb, which are seen to undergo elongation ($s$), as they are pushed upwards by the development of new cells beneath; and thus, as they

Fig. 35.

Hair-bulb of a well-developed *Human Hair*, with its *follicle*:—*a*, medullary substance, containing air-spaces, with indistinct cells; *b*, fibrous cortical substance; *c*, *d*, inner and outer layers of the scaly envelope; *e*, *f*, inner and outer layers of the internal root-sheath; *g*, external root-sheath; *h*, structureless membrane; *i*, transverse-fibre-stratum; *k*, longitudinal fibre-stratum; *l*, hair-papilla; *m*, lowest cells of the hair-bulb, continuous with those of the external root-sheath; *n*, perpendicularly-arranged nucleated cells, which, near *q*, become non-nucleated, and are continuous with the inner layer of the scaly envelope; *o*, small perpendicularly arranged cells, likewise nucleated, passing into the outer layer of the same; *p*, lowest portion of the inner root-sheath; *r*, commencement of the medullary substance in the condition of colourless cells; *s*, part where the cells of the bulb begin visibly to lengthen themselves, to form the fusiform cells of the shaft.

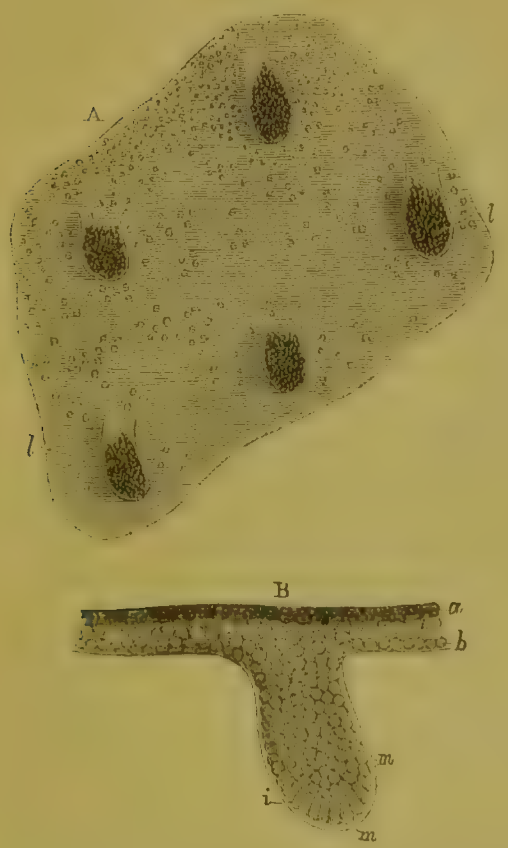
* According to Prof. Kölliker, it is by the laceration of a layer of flattened cells without nuclei, which forms the outer stratum of the inner layer of the root-sheath, that the so-called 'fenestrated membrane' is produced, the presence of which between structures corresponding to the Malpighian and horny layers of the Epidermis, has been a subject of much perplexity to Microscopists.

are at the same time narrowed, the shaft comes to be of less diameter than the bulb at its base. The cells of the medullary substance are derived with less change from those of the interior of the hair-bulb; they are at first colourless ($r$), but gradually acquire the dark aspect which is partly due to the development of pigmentary matter, but still more to the production of air-spaces by their desiccation.—Thus we see that the whole tissue of the Hair is derived from Epidermic cells, developed in peculiar abundance from the surface of the papilla at the base of the follicle, which is itself extremely vascular; some of these cells retaining their original form, whilst others are transformed into fibres, and others converted (like those of ordinary Epidermis) into flattened cells. They all have the power, however, of drawing horny matter into their cavities; and resist the solvent power of chemical re-agents, except when these are employed in unusual strength.—The Hair is constantly undergoing elongation, by the addition of new substance at its base; and the part which has been once fully formed, and which has emerged from the follicle, usually undergoes no subsequent alteration. There is evidence, however, that it *may* be affected by changes at its base, the effect of which is propagated along its whole extent: thus, it is well known that cases are not unfrequent, in which, under the influence of strong mental emotion, the whole of the hair has been turned to grey, or even to a silvery white, in the course of a single night; a change which can scarcely be accounted for in any other way, than by supposing that a fluid, capable of chemically affecting the colour, is secreted at the base of the hair, and transmitted by imbibition through the medullary substance, to the opposite extremity. Another evidence of their retention of a degree of vitality, is found in the fact of Hairs having a tendency to become pointed, after having been cut short off. In the hairs of some animals (particularly the whiskers of the Seal and other Carnivora) the base is hollow, and contains a large papilla, or elevation of the cutis, furnished with nerves and blood-vessels; this is separated, by a layer of basement-membrane, from the proper tissue of the Hair. In such cases, there is bleeding from the stumps of the hairs, when they are shaved off close to the skin. We have seen that there is an approach to this papillary structure in Man; and it may perhaps be an abnormal development of it, which occasions the hair to bleed in the disease termed Plica Polonica. The hair of individuals affected with this, is further disposed to split into fibres, often at a considerable distance from the roots, and to exude a glutinous substance; these two causes unite in occasioning that peculiar *matting* of the hair, which has given origin to the name of the disease.

247. The history of the embryonic development of the Hair has recently been made the subject of careful study by Prof. Kölliker; and the following is the substance of his account of it. The hair-rudiments may be said to be composed of little processes of the Malpighian layer of the epidermis, which are received into corresponding depressions in the corium (Fig. 36, A, $l$, $l$); these are soon perceived to be inclosed in a limiting membrane (B, $i$), which separates the contained cells ($m$, $m$) from the interior of the follicle, just as the basement-membrane of the Skin with which it is continuous, separates the Malpighian layer of the Epidermis from the corium. The hair-matrix now lengthens and swells out at the bottom, so as to assume a flask shape. Cells are deposited

outside the limitary membrane, which are eventually converted into, or give place to, fibres; and thus the dermic coats of the follicle are produced.—But whilst this is going on outside, the cells within the follicle undergo changes. Those in the middle lengthen out conformably with the axis of the follicle, and constitute a short conical miniature hair, faintly distinguishable by difference of shade from the surrounding mass of cells, which are also slightly elongated, but transversely with regard to the follicle (Fig. 37, A). The papilla (B, *h*) makes its appearance at the swollen root of the little hair; and the residuary cells contained within the rudimentary follicle form the root-sheath, the inner layer of which (*f*) lying next to the hair, is soon distinguished by its translucency from the more opaque outer layer (*c*) that fills up the rest of the cavity. The young hair, continuing to grow, at last perforates the epidermis (c), either directly, or after first slanting up for some way between the Malpighian and the horny strata. In the former case it may, perhaps, be aided in its progress by the harder inner layer of the root-sheath, which accompanies the hair, and makes way for it through the cuticle. Prof. Kölliker further thinks it not improbable that the eruption of the hairs is facilitated by the general desquamation and shedding of the superficial part of the epidermis, which occurs from time to time during fœtal life; more especially as the period of most thorough desquamation begins at about the same time as the first eruption of hairs.—A shedding of the first-formed hairs, or *lanugo*, is known to take place before birth; but, according to Prof. Kölliker, only to an inconsiderable extent. On the other hand, he has observed that the infantile hairs are entirely shed and renewed within a few months after birth; those of the general surface first, and afterwards the hairs of the eyebrows and head, which he finds in process of change in infants about a year old. The new hairs are generated in the follicles of the old, as previously seen by Heusinger and Kohlrausch in quadrupeds; but Kölliker describes the steps of the process somewhat differently from his predecessors. He conceives that an increased growth of cells takes place in the soft hair-bulb and in the adjoining part of the root-sheath (Fig. 38, A); the growing mass protrudes or lengthens out

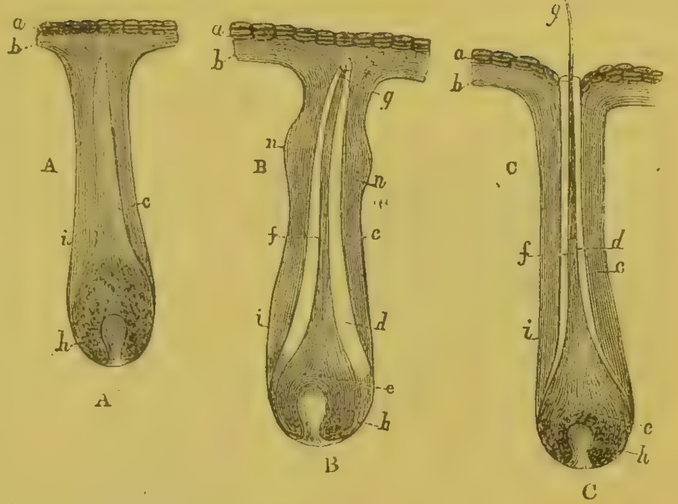
Fig. 36.




A, Development of the *Hair-bulbs* in the Epidermis of the forehead, in a human fœtus of sixteen weeks, as seen from the under side;—B, a single hair-matrix more enlarged, as seen laterally:—*a*, horny layer of the epidermis; *b*, mucous layer of the same; *i*, structureless membrane surrounding the hair matrix, prolonging itself from betwixt the mucous layer and the corium; *m*, rounded, with some elongated cells, forming the matrix of the hair.

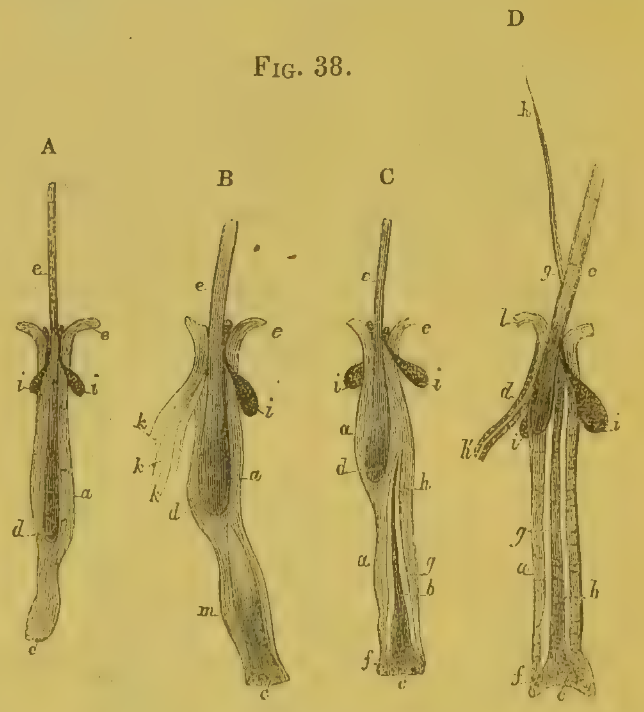
the lower end of the hair-follicle into a process, at the bottom of which is found the generative papilla ($c$), now, by the interposition of the new cell-growth, withdrawn from the root of the hair. The newly-formed mass of cells, occupying the lower or prolonged part of the follicle, and resting on the papilla (B, $m$), is gradually converted into a new hair (c, $f$, $g$, $h$) with its root-sheath ($b$), just as happens n the primitive process of formation in the embryo; and as the new hair lengthens and emerges from the follicle (D, $g$), the old one ($d$, $e$), detached from its matrix, is gradually pushed nearer to the opening, and t last falls out, its root-sheath having previously undergone a partial absorpion.—A similar death of he old hairs, and replacement by new ones generated vithin the same follicles, eems to take place at inervals through the whole f life; and it is obvious, as Ir. Paget has pointed out, hat the death of the old air is not the consequence f absorption at its root aused by the development f a new one beneath it, but s simply the termination f a series of degenerative hanges that have been for ome time in progress.* his is one illustration, out f many that might be cited, f the general fact of the *mited duration* of the inividual parts of the living rganism (§ 114); the inteity of which is maintained

Fig. 37.



Development of the *Hair* in the eyebrow:—A, first distinct separation of the inner and outer portions of the hair-matrix;—B, first formation of the hair, whose point has not yet appeared above the skin;—C, the hair soon after its first emersion:—$a$, horny layer of the epidermis; $b$, its mucous layer; $c$, outer root-sheath; $d$, inner root-sheath; $e$, hair-bulb; $f$, hair shaft; $g$, point of the hair; $h$, hair papilla; $i$, structureless membrane on the exterior of the matrix; $n$, commencement of the sebaceous glands.

Fig. 38.



Development of *Second Eyelashes* in an Infant of a year old:—A, incipient formation of matrix of second hair;—B, incipient development of the young hair, the outer and inner portions not yet distinct;—C, the young hair, more advanced, and pushing up the old hair; its proper substance distinct from the root-sheath;—D, the young hair emerged from the opening, and its predecessor about to fall out:—$a$, external root-sheath; $b$, internal root-sheath of young hair; $c$, cavity for the reception of the formative papilla; $d$, bulb of the old hair; $e$, its shaft; $f$, bulb of the young hair; $g$, its shaft; $h$, its point; $i$, $i$, sebaceous glands; $k$, $k$, sweat-canals; $l$, passage of the external root-sheath into the mucous layer of the epidermis; $m$, first appearance of young hair.

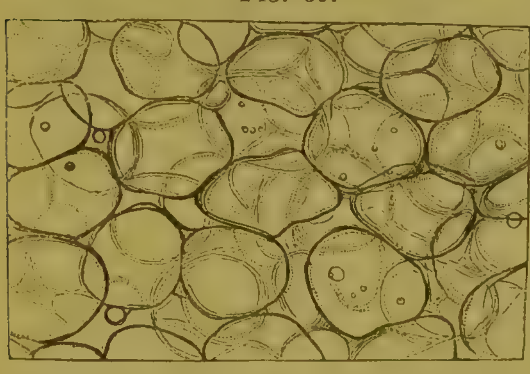
* See Kirkes and Paget's "Hand-book of Physiology," 2nd edit. pp. 285-8.

by the continual development of new structure, in place of that which is become effete.—The *regeneration* of Hairs which have been plucked out of their follicles is very complete; provided the follicles themselves, and their papillæ, have not been injured. The cavity of the follicle (according to the observations of Heusinger) is at first filled with blood, which is gradually absorbed; a dark spot, consisting of a cluster of newly-formed epidermic cells containing pigmentary matter, is seen upon the summit of the papilla; and this gradually elongates itself, and undergoes development into the several parts of the new hair and of its sheath, just as in the case of the first evolution.

### 3. *Of the purely Cellular Tissues;—Fat and Cartilage.*

248. The *Adipose* tissue, which is only second to the Areolar in the extent of its diffusion through the Human body, continues, throughout life, to present the primitive cellular type in its purest form; this tissue, wherever it occurs, being composed of an aggregation of cells, which never depart widely from the spheroidal form (Fig. 39), the chief alteration in shape which they undergo being the flattening of their walls from mutual pressure (Fig. 125). Fat-cells are dispersed among the interspaces of Areolar tissue, in most, but not all, of the situations in which the latter presents itself; but there are certain situations in which they are developed more abundantly, filling up interstices, and forming a pad or tissue for the support of moveable parts. In all but very emaciated individuals, there is a considerable amount of fat beneath the skin; and it is in great part to its interposition, that the roundness and smoothness of the surface, especially in the female, are due. But fat is collected in large quantities around certain internal organs, as the kidneys, where its use is less obvious; and here, as well as at the base of the heart around the origin of the large vessels, in the orbit of the eye, in the interior of the bones, and within the spinal canal between the periosteum and the dura mater, some fat is always left, however extreme may be the general emaciation.—The diameter of the greater number of Fat-cells is between 1-300th and 1-600th of an inch; but larger and smaller sizes are frequently to be met with. The nucleus is seldom to be distinguished in the fully-developed fat-cell; but it is probable that it has not ceased to exist there, but is simply obscured by the oily cell-contents. For not only does a nucleus exist in the fat-cells of the embryo, which are at first pellucid vesicles, then become granular, and at last acquire oily contents; and also in the rudimentary fat-cells closely resembling these in their successive stages, which are described by Prof. Kölliker as existing in the Dartos; but also in fat-cells wholly deprived of their oily contents, which are not unfrequently met with in emaciated or dropsical subjects.—When the fat-cells are aggre-

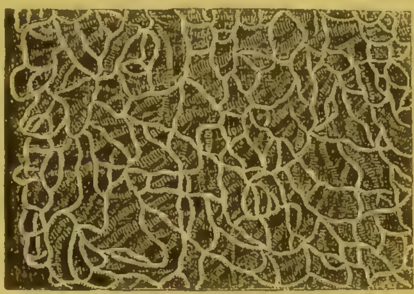
Fig. 39.



Cells of *Adipose* Tissue. Magnified 135 diameters.

gated so as to form masses of Fat, they are first collected into little lobular clusters, each of which has a delicate membranous investment; and these are again united into larger clusters, visible to the naked eye, whose further aggregation may form masses of considerable size. The component parts of these are held together by Areolar tissue, and also by the blood-vessels which penetrate them, and which ramify minutely among them, forming a capillary network, not only upon the surface of the smallest lobules, but even (it would appear) between their contained fat-cells (Fig. 40). In some forms of Adipose tissue, such as the marrow of bones, it would seem that very little areolar tissue exists, or that it is even entirely absent; and here the capillary plexus forms the principal bond of union between the fat-cells. No lymphatics have been detected in Adipose tissue; and it would seem to be equally destitute of nerves, excepting of such as are passing through it on their way to other textures; thus accounting for the known fact of its being insensible except when those trunks are injured.—The physical and chemical characters of the oleaginous substances contained within the fat-cells, have already been sufficiently described (§§ 37, 38). The Margarin, which is the principal solid constituent of Human fat, is dissolved in the Olein, forming a thick oil, which remains fluid at the ordinary temperature of the body, but congeals when cooled much below it. That this oil does not escape from the fat-cells during life, may be attributed to the moistening of their walls by the aqueous fluid circulating through their vessels; but we find that the contents of the fat-cells *are* taken back into the general current of the circulation, when the food does not afford an adequate supply for the purposes of respiration; and we may probably explain this by the alkalinity of the blood, which enables it to exert a certain solvent power for oleaginous matter, and which, when the amount ordinarily present in the blood has been exhausted, or nearly so, will be exercised upon the fat within the cells of adipose tissue, and will draw it into the circulating current.*

Fig. 40.



Capillary net-work around *Fat-cells.*

249. The relative quantity of Fat contained in the bodies of different individuals, varies more than does that of any other tissue. If there be no incapacity for the production of fat-cells, the amount of Adipose tissue generated will depend upon the quantity of their appropriate *pabulum* that may be supplied; and this is, in fact, the surplus of the oleaginous matter ingested in the food, or formed from its other constituents, after the various demands made upon it by the wants of the system in general (§§ 41, 42) have been supplied. Hence the formation of fat will be promoted by the use of oleaginous food, by inactive habits of life, and by warmth of the surrounding atmosphere; and it is by attention to these indications, that the breeders of animals obtain the largest production of

* It has been shown by Prof. Matteucci, that fatty matters, suspended in water in a state of fine division, on one side of a membranous septum, will pass through it endosmotically towards a weak alkaline solution on the other. (See his "Lectures on the Physical Phenomena of Living Beings," Dr. Pereira's edition, p. 111.)

fat in the shortest time. There appears to be, among some individuals, an extraordinary tendency to the development of Adipose tissue, which may thus appropriate to itself the nutriment that is destined for the supply of other parts; and this sometimes shows itself throughout the body, constituting general Obesity or Polysarcia, and sometimes in individual parts, forming Lipoma or fatty tumour. Although general Obesity is doubtless favoured by the conditions just referred to, yet it may develope itself under circumstances of a very different kind; namely, when the food is neither rich nor abundant, when active exercise is taken, and when the individual habitually exposes himself to a cool atmosphere. And we cannot but here recognize the same kind of excessive developmental power in the Adipose tissue, as shows itself locally in tumours, which will even grow and increase when the body generally is in a state of extreme emaciation. On the other hand, there are individuals in whom there is an obvious deficiency in the power to generate this tissue; since they never become otherwise than lean, even under the most favourable conditions. Such persons, moreover, are usually very apt to become 'bilious' when they take-in much oleaginous matter with their food; for if the surplus be not drawn off from the blood in the generation of Adipose tissue, it is probably thrown for elimination upon the Liver, which organ is very prone to be disordered by being called into excessive functional activity.

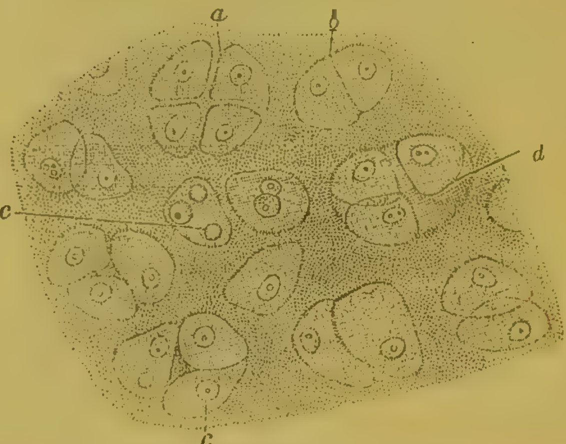
250. Besides the support, combined with facility of movement, which Fat affords to the moving parts of the body, it answers the important purpose of assisting in the retention of the animal temperature, by its non-conducting power; and the still more important object, of serving as a kind of reservoir of combustible matter against the time of need. Herbivorous animals, whose food is scanty during the winter, usually exhibit a strong tendency to such an accumulation, during the latter part of the summer, when their food is most rich and abundant; and the store thus laid up is consumed during the winter. This is particularly evident in the hybernating Mammalia, which take little or no food during their seclusion. Again, when Birds or Mammals are deprived of food, the duration of their lives is proportional, *cæteris paribus*, to the amount of fat they contain; the immediate cause of death in such cases being the reduction of the temperature of the body, which takes place as soon as the store of combustible material is exhausted (CHAP. XIII.). If there were no such store within the system, we should be dependent upon a *constant* supply of aliment for our heat-producing power; and the loss of even a single meal might be fatal. This condition is seen in animals which have been brought to the verge of starvation, and which are only at first capable of digesting a small quantity of food; for, as Chossat's experiments have shown, until they have in some degree replaced their fat by the assimilation of *surplus* nutriment, they cannot sustain life except by the assistance of artificial heat.*

251. In *Cartilage*, also, the simple *cellular* structure is very obviously retained, and frequently exists alone; although in some forms of this tissue, it is united with the fibrous, or is partly replaced by it. In all, however, the early stage of formation appears to be the same. The structure

* See his "Recherches Expérimentales sur l'Inanition."

originates in cells, analogous to those of which the rest of the fabric is composed; but between these cells, a large quantity of hyaline or intercellular substance, consisting of Chondrin (§ 34), is soon deposited; and the amount of this substance usually continues to increase simultaneously with the bulk of the cells. The original cells are pushed farther and farther from one another; but new cells arise between them, from germs which are contained in the hyaline substance. The first cells frequently produce two or more young cells by subdivision (§ 104), and this act may be repeated; and thus it is very common to meet with groups of such cells or corpuscles, consisting of two, three, or four (Fig. 41). These groups, in the Articular cartilages, which may be considered as the types of the purely cellular form, usually lie perpendicularly in the deeper part of the cartilage (that nearest the attached surface), and obliquely or irregularly as they approach the free surface, whilst at and near that surface they lie parallel to it. The deeper groups are composed of a larger number of cells than the superficial; and in the stratum forming the free surface, single isolated cells are not unfrequent, which have been mistaken for epithelium-cells. The free surface is covered in the fœtal state by a synovial membrane; of which the two characteristic elements, — basement-membrane and epithelial cells, — may be clearly recognized. But after birth, this membrane seems to be gradually destroyed by pressure and attrition, and by the retirement of the superficial vessels towards the circumference; and appears in the adult to terminate at the margin of the cartilage, very little in advance of the 'circulus articuli vasculosus.'—The matrix of the cartilage-cells is not so perfectly homogeneous, as its appearance in thin sections would seem to indicate; for when a shred of it is detached from the edge of a fractured cartilage, it is found to tear in a distinctly filamentous manner; and the arrangement of the filaments corresponds with that of the cells, being perpendicular to the attached surface of the cartilage, and parallel to its free surface, where it forms with the cells a sort of membranous layer that has been mistaken for synovial membrane.* It is interesting to observe, that this filamentous arrangement of the intercellular substance becomes much more obvious in certain diseased states of articular cartilages; and that, concurrently with this change, its chemical composition alters from chondrin to glutin.†

FIG. 41.



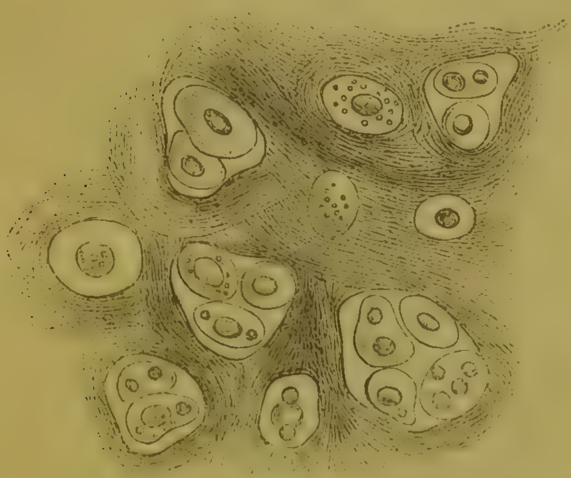

Section of the branchial *Cartilage* of Tadpole:—*a*, group of four cells, separating from each other; *b*, pair of cells in apposition; *c, c*, nuclei of cartilage cells; *d*, cavity containing three cells.

* See the excellent account of the structure of Cartilage by Prof. Sharpey, in his Introduction to "Quain's Elements of Anatomy," 5th edit.; and Dr. Leidy's Memoir 'On the Intimate Structure and History of Articular Cartilages,' in the "Amer. Journ. of Med. Sci.," April, 1849.

† This was first pointed out by Dr. Redfern, in his admirable Treatise on "Anormal Nutrition in the Human Articular Cartilages."

252. The varieties in the permanent Cartilages principally depend upon the degree of organization which subsequently takes place in the intercellular substance. If a mass of Fibres, analogous to those of the fibrous membranes (§ 220), should originate in it, the Cartilage presents a more or less fibrous aspect (Fig. 42); in some instances the Fibrous structure is developed so much, at the expense of the Cells, that the latter disappear altogether, and the whole structure becomes fibrous. Sometimes the fibres which are developed, are rather analogous to those of the Elastic tissue (§ 221); these are disposed around the cells, forming a kind of network, in the areolæ of which they lie; and this kind of cartilage may be termed the elastic or reticular. —The primitive *cellular* organization is for the most part retained in the ordinary articular cartilages,* the cartilaginous septum narium, the cartilages of the alæ and point of the nose, the semilunar cartilage of the eyelids, the cartilages of the larynx (with the exception of the epiglottis), the cartilage of the trachea and its branches, the cartilages of the ribs (in Man), and the ensiform cartilage of the sternum; and it is seen also in the temporary cartilages, or those which are destined to undergo ossification. The *fibrous* structure is seen in all those Cartilages, which unite the bones by synchondrosis; this is the case in the vertebral column and pelvis, the cartilages of which are destitute of corpuscles, except in and near their centres. In the lower Vertebrata, however, and in the early condition of the higher, the fibrous structure is confined to the exterior, and the whole interior is occupied by the ordinary cartilaginous corpuscles. The *reticular* structure is best seen in the epiglottis and in the concha auris; in the former of these, scarcely any trace of cartilage-cells remains; in the latter, the fibrous net-work disappears by degrees towards the extremity of the concha, and the structure gradually passes into the cellular form.†

Fig. 42.



Section of *Fibro-Cartilage*; showing disposition of cartilage-cells, in areolæ of fibrous tissue.

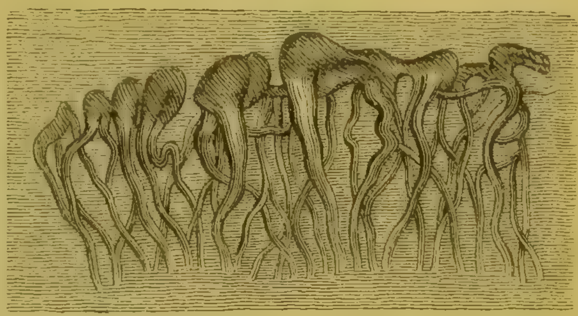
253. Cartilage (at least in its simplest form) is nourished without coming into direct relation with the Blood through the medium of blood-vessels; for the *cellular* Cartilages are not penetrated by vessels in the healthy state; and although in certain diseased conditions they seem to become distinctly vascular, yet the vessels do not extend into the substance of the cartilage itself, but are restricted to the new tissue in which they are developed. Cartilages, however, are *surrounded* by Blood-vessels; which form large ampullæ or varicose dilatations at their edges or on

* The articular cartilages, at the points where tendons are implanted into them, have all the characters of fibro-cartilage; the fibres of the tendon being spread through the intercellular substance of the cartilage, for some distance, and gradually coalescing with it.

† See Mr. Toynbee's Memoir on the 'Non-Vascular Tissues,' in "Phil. Trans.," 1841.

their surfaces (Fig. 43): and from these the Cartilages derive their nourishment by imbibition, in exactly the same manner as the frond of a sea-weed (the structure of which is alike cellular) draws into itself the requisite fluid from the surrounding medium. In the thicker masses of cartilaginous tissue, however, such as the cartilages of the ribs, we find canals excavated at wide distances from each other; which are lined by a continuation of the perichondrium or investing membrane of the cartilage, and which thus allow its vessels to come into nearer proximity with parts, that would be otherwise too far removed from them. The vessels, however, nowhere pass from the walls of these canals into the substance of the cartilage. Similar vascular canals are found in the temporary cartilages, near the points where the ossifying process is taking place; this is well seen in the long bones, towards their extremities. At an early period of fœtal life, there is no distinction between the cartilage that is ultimately to become the Osseous Epiphysis, and that which is to remain as Articular Cartilage; both are alike cellular; and the vessels that supply them with nutrient materials penetrate no further than their surfaces. At a subsequent period, however, when the ossification of the epiphysal cartilage is about to commence, vessels are prolonged into it; and a distinct line of demarcation is seen betwixt the *vascular* portion, which is to be converted into Bone, and the *non-vascular* part, which is to remain as

Fig. 43.



Vessels between the *Articular Cartilage* and attached *Synovial Membrane*.

Fig. 44.


Vessels situated between the *Articular Cartilage* and the attached *Synovial Membrane* at the point where the ligamentum teres is inserted in the head of the os femoris of the human subject, between the third and fourth months of fœtal life:—*a*, the surface of the articular cartilage; *b*, the vessels between the articular cartilage and the synovial membrane; *c*, the surface to which the ligamentum teres was attached; *d*, the vein; *e*, the artery.

Cartilage. At this period, the Articular Cartilage is nourished by a plexus of vessels spread over its free surface, beneath its synovial membrane (Fig. 44); as well as by the vessels, with which it comes into contact at its attached extremity. Towards the period of birth, however, the sub-synovial vessels gradually recede from the surface of the articular cartilage; and at adult

age they have entirely left it, though they still form a band, the 'circulus articuli vasculosus,' which surrounds its margin. The Fibrous cartilages are somewhat vascular; but the vessels do not extend to the cellular portions, where such exist.—Neither lymphatics nor nerves can be traced into the substance of Cartilage; which may be affirmed with certainty to be completely insensible, and this in the state of disease as well as of health.* The blood-vessels which appear to pass into Cartilages in a state of Inflammation, do not really penetrate its substance, but are limited to the false membrane which is developed *de novo*, and which not only covers the surface of the cartilage, but also dips down into all the inequalities which are produced by its loss of substance. The usual rate of its nutrition is probably very slow. Its functions, save where it undergoes subsequent transformation, are purely mechanical; and though it is continually subjected to *pressure*, yet the extreme smoothness of its surfaces, and their constant lubrication by the synovial fluid, diminish *friction* so much as to render this a very slight cause of disintegration. It is not at all uncommon, however, for Articular cartilages to be almost entirely destroyed through 'anormal nutrition;' and this without any pain or other symptom to call attention to the change in progress.† This process essentially consists in the enlargement of the cartilage-cells, the conversion of their nuclei into a multitude of corpuscles, the fusion of the walls of the cells with the hyaline substance, and the rupture of the cells, whereby the contained corpuscles are set free. At the same time, the hyaline substance gradually comes more and more to present a fibrous appearance; and the whole may thus degenerate, until scarcely a trace of the original cartilaginous structure is left. The progress of disease is sometimes arrested, however; and a natural cure is effected by the development of a white fibrous membrane from the intercellular substance, with which yellow fibres are intermingled that are derived from the cell-nuclei. And it is in this way that the attempt is made to bring together the two edges of an incised wound, or to fill up loss of substance occasioned by the actual removal of Cartilaginous tissue; for it does not appear that any power exists in Cartilage to generate new tissue of its own kind for such purposes. Many weeks or even months are required by this process; and hence some observers have altogether denied that *any* reunion of incised wounds of Cartilage, or any filling-up of breaches of surface, ever takes place. (See Redfern, Op. cit.) It is curious that fractures of certain cartilages (as those of the ribs) are commonly repaired by *osseous* union; a fact which seems to have reference to the normal ossification of these cartilages among many of the lower animals, and to their not unfrequent conversion into bone in the latter period of life in the Human subject.

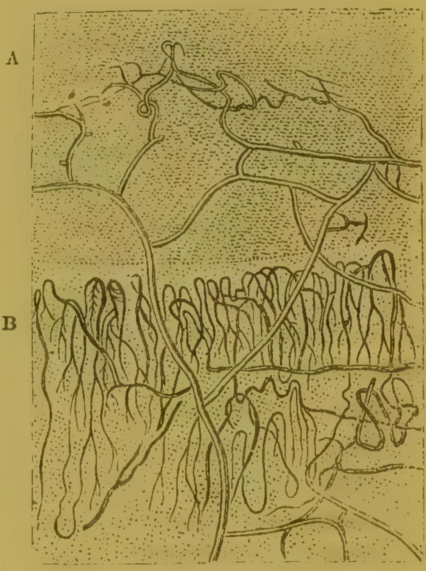
254. The *Cornea* of the eye bears but a slight resemblance to Cartilage in regard to its intimate structure, though it corresponds with it closely in the mode of its nutrition. Besides its anterior or conjunctival layer, which consists of three or four strata of epithelium-cells, and its posterior

* That the acute pain which so commonly occurs in diseases of joints implicating the Articular Cartilages, is not to be referred, as it usually has been, to the cartilage, but to the subjacent bone, has been in the Author's opinion most satisfactorily proved by Dr. Redfern in his Treatise on "Anormal Nutrition in the Human Articular Cartilages."

† See Redfern, Op. cit.

ayer of cells constituting the epithelium of the aqueous humour, the Cornea proper has been shown by Mr. Bowman* to consist of three layers, hich he designates respectively as the 'anterior elastic lamina,' the lamellated cornea,' and the 'posterior elastic lamina.'—The lamellated issue which makes up the principal substance of the cornea, consists of uperposed lamellæ, which are individually of no great extent, but are onnected together both horizontally and vertically by membranous rolongations; about sixty of these lamellæ are estimated to intervene etween any two corresponding spots on the opposite surfaces of the issue; and each of them seems, when highly magnified, to present a intly fibrous texture. The interspaces left between the superposed layers ave the form of tubes, arranged with tolerable regularity, and constricted t intervals; these are more readily demonstrated, however, in the corneæ f large quadrupeds than in that of man. This lamellated tissue is the nly part of the cornea, which is continuous with the sclerotica; and its bres appear to be very similar, in every respect save their extreme trans- arency, to those of that tissue.—The anterior elastic lamina is a very iin stratum of homogeneous membrane, not affected by maceration, boil- ng, or acids, which intervenes between the epithelial layer and the mellated tissue; apparently serving as a 'basement-membrane' to the rmer; whilst it is tied down to the latter by filaments of elastic tissue, hich pass from its internal surface to lose themselves among the super- cial lamellæ. This layer disappears at the margin of the cornea, expend- g itself apparently in giving origin to an increased number of these aments, some of which pass into the scle- tic coat.—The posterior elastic lamina r 'membrane of Demours' or 'of Des- met') resembles the anterior in the cha- cters of its texture; but its adhesion to e posterior surface of the lamellated cor- a is comparatively slight, no filaments ing sent down from it among the la- ellæ.—No vessels can be traced into the bstance of the Cornea; but its margin (like at of an articular cartilage) is surrounded a circle of vessels, consisting of two sets, superficial and a deep-seated (Fig. 45). e arteries of the former, according to r. Toynbee,† are derived from the Con- nctival membrane, and are prolonged for short distance upon the outer layer of the rnea; but they terminate in veins at m $\frac{1}{8}$ to $\frac{1}{2}$ a line from its margin. The ep-seated vessels are derived from the lerotic; and they terminate in veins just ere its tissue becomes continuous with at of the Cornea. In diseased conditions the Cornea (as of the articular cartilages), both sets of vessels extend

Fig. 45.




Nutrient *Vessels of the Cornea*:—A, superficial vessels belonging to the Conjunctival membrane, and continued over the margin of the Cornea; B, vessels of the Sclerotic, returning at the margin of the Cornea.

* "Lectures on the Parts concerned in the Operations on the Eye," pp. 10–22, and Todd Bowman's "Physiological Anatomy," vol. ii. p. 18.

† "Philosophical Transactions," 1841.

themselves through it; the superficial not unfrequently form a dark band of considerable breadth round its margin; whilst the deep-seated are prolonged into its entire substance. Notwithstanding the absence of vessels in the healthy condition of this structure, incised wounds commonly heal very readily, as is well seen after the operation of extraction of Cataract; but the foregoing details make evident the importance of not carrying the incision further round than is necessary; since the corneal tissue should not be cut off from the supply of nourishment afforded by the vessels in its immediate proximity.

255. The *Crystalline Lens* of the Eye approaches cartilage, in its structure and mode of nutrition, more nearly than any other tissue. It may be separated into numerous laminæ, which are composed of serrated fibres that lock into one another by their delicately-toothed margins;* these serrations, however, are much less obvious on the margins of the fibres of the human crystalline, than they are in those of the lenses of fishes. Each fibre appears to be made up of a series of cells, which coalesce with each other at an early period; and these are indicated, even in the fully-formed fibres, by nuclei which present themselves at pretty regular intervals in their substance. A layer of unconverted cells, extremely thin and transparent, of unequal size, and nucleated, is always found between the surface of the lens and its capsule, which it brings into organic union. The capsule is perfectly transparent, homogeneous, and very elastic; it forms a perfectly close envelope, admitting neither vessels nor nerves to the contained lens; but it is very readily permeable to fluids, as is shown by the absorption from the aqueous humour that sometimes takes place after death, giving rise to the so-called 'liquor Morgagni,' the presence of which, according to Mr. Bowman (Op. cit., p. 70), is not the normal condition. The lens itself is at no period of its existence supplied with blood-vessels, these being confined to the capsule. During the early part of fœtal life, and in inflammatory conditions subsequently, both the anterior and posterior portions of the capsule are distinctly vascular; the latter being supplied from the arteria centralis retinæ, which expands upon it after having traversed the vitreous humour, and sends branches that pass round the margin, to be distributed, with twigs from the ciliary processes, upon the anterior surface. The loops formed by the latter gradually retreat, during fœtal life, from the centre towards the margin, like those of the synovial membranes; and after a time, the posterior capsule also ceases to be vascular. The subsequent growth of the crystalline lens appears to be very trifling, and appears to be sufficiently provided for by imbibition through its capsule, from the aqueous and vitreous humours which are in contact with its two surfaces respectively. The substance of which the lens is composed seems to be chemically identical with the Globulin of the blood-corpuscles (§ 23); it contains about 58 per cent of water. Cases of the regeneration of the crystalline lens, after its complete removal by extraction, have been put upon record;† but such a reparation must be extremely rare, and is probably limited to young subjects.—The *Vitreous body* has been commonly supposed to consist of a loose fibrous network, the areolæ of which

* See Sir David Brewster, in "Philos. Transact." 1833.

† See especially the observations of Dr. Pauli in the "Monatschrift für Medicin," Jan. and Feb., 1839; cited in the "Brit. and For. Med. Rev.," vol. viii. p. 247.

.re filled up with fluid, that drains away slowly when the membrane is ›unctured; but this notion of its structure was purely hypothetical, ıeither fibres nor cells having been made out by any anatomist. Atempts have been recently made by Brücke and Hanover to prove that his body has a laminated structure; but much of the evidence adduced y them has been shown by Mr. Bowman* to be fallacious. Some such rrangement may be clearly made out, however, in the vitreous body of he Fish's eye, and a definite fibrous texture is distinguishable in that of he Bird; so that it is probable that some approach to it exists in the itreous body of Man. Whatever may prove to be its intimate structure, ıe nutrition of this substance is certainly effected by the same means ith that of the cornea and crystalline; namely, by imbibition from the essels distributed upon or near its envelope. The ciliary processes of the horoid membrane are almost entirely composed of large ampullated essels, closely resembling those of synovial membrane (Fig. 43); and ıe blood which they contain is probably one of the chief sources of utriment to the vitreous body. The reproduction of the Vitreous body, ı escape of portions of which is not at all an unfrequent occurrence ıring the performance of operations upon the eyes, seems to take place ith great rapidity and completeness.

4. *Of the Tissues consolidated by Earthy deposit;—Bones and Teeth.*

256. Both the *Fibres* and *Cells* of the Animal tissue may be consoliıted by earthy deposits; these being chemically united with the gelatin the Fibres; or secreted, either alone, or in combination with animal atter, into the cavities of the Cells. An example of the formation of a eleton by the consolidation of *fibres,* is presented by the shell and other rd parts of the Echinodermata;† the intimate structure of which, as own by the Microscope, strongly reminds us of Areolar tissue that ight have undergone the calcifying process. Again, we have an example the formation of a skeleton by the deposit of mineral matter in the vities of *cells,* in the shells of Mollusca;‡ in many of which (especially ıong the 'bivalves') the cellular character is permanently shown, a content membrane being left after the carbonate of lime that consolidated e cells has been dissolved away by an acid,—an arrangement precisely nilar to that which is found in the Enamel of teeth (§ 275), though e consolidating material is different. In the skeletons of Invertebrated imals, which, with few exceptions are dermal or tegumentary, there is provision for any other mode of increase than that which is effected addition to the surface or edges of the parts already formed; and ıere, as in the Crustacea, such an addition would not serve to maintain form of the calcified envelope, and to preserve its adaptation to the ıscular apparatus which is attached to its interior, it is periodically own off and renewed. And in the very few cases in which absorption ces place for the removal of parts that have become superfluous, this sorption, like the previous deposition, is superficial only; and is effected

"Lectures on the Parts concerned in the Operations on the Eye," p. 94 et seq.; also "Dubl. Quart. Journ. of Med. Sci.," Aug. 1848.
See "Princ. of Phys., Gen. and Comp.," § 195.
Op. cit. § 197.

by the mere contact of an absorbent surface, without any penetration of vessels into the substance to be removed. The Osseous skeleton of the Vertebrated animal, on the other hand, is essentially formed by the consolidation of the tissues immediately surrounding the nervous centres, and of outgrowths from these;* it is invested by the muscular apparatus, which gives motion to its different parts; and in order that it may keep pace with the progressive growth of the organism in general, it must be made capable not merely of receiving additions to its surface, but also of having its interior gradually consolidated by new deposits, and, in like manner, of having the parts first laid-down removed by subsequent absorption from within as well as from without. Even when the full growth of the skeleton has been attained, nutritive changes still take place in it; and the continuance of these seems to be destined, not so much to supply any waste occasioned by decomposition,—for this must be very trifling in a tissue of such solidity,—as to keep the fabric in a condition, in which it may repair the injuries in its substance occasioned by accident or disease. The degree of this reparative power we shall find to be proportional to the activity of the normal changes which are continually taking place in the osseous tissue; and is thus much greater in youth than in middle life, and in the vigour of manhood than in old age.

257. When the compact Osseous substance of the shaft of a long bone, or of the superficial portions of a flat bone, is examined with the naked eye, it is seen to possess a somewhat laminated texture; the external and internal laminæ of the long bones being arranged concentrically round the medullary canal, whilst in the flat bones they are parallel to the surface. Towards the extremities of the long bones, and between the external plates of the flat bones, are a number of *cancelli*, or small hollows bounded by very thin plates of bone; these communicate with the medullary canal where it exists; having, like it, an extremely vascular lining membrane; and their cavities being filled with a peculiar adipose matter. Even the hard substance of the bone is traversed by canals, on which the name of 'Haversian' has been bestowed, after their discoverer; these canals run for the most part in the direction of the laminæ; but they have many transverse communications, both with each other and with the medullary cavity, so that they form a complete net-work (Fig. 46), which is lined by a continuation of the membrane of the latter. Their diameter varies from 1-200th to 1-2000th of an inch; the average being probably about 1-500th. The smaller ones contain only a single capillary vessel; but several such vessels seem to exist in the larger ones, together with adipose matter. When a thin transverse section of a long bone is made, and is highly magnified, it is seen that the bony matter of the greater part of its thickness is arranged in concentric circles round the orifices of the canals

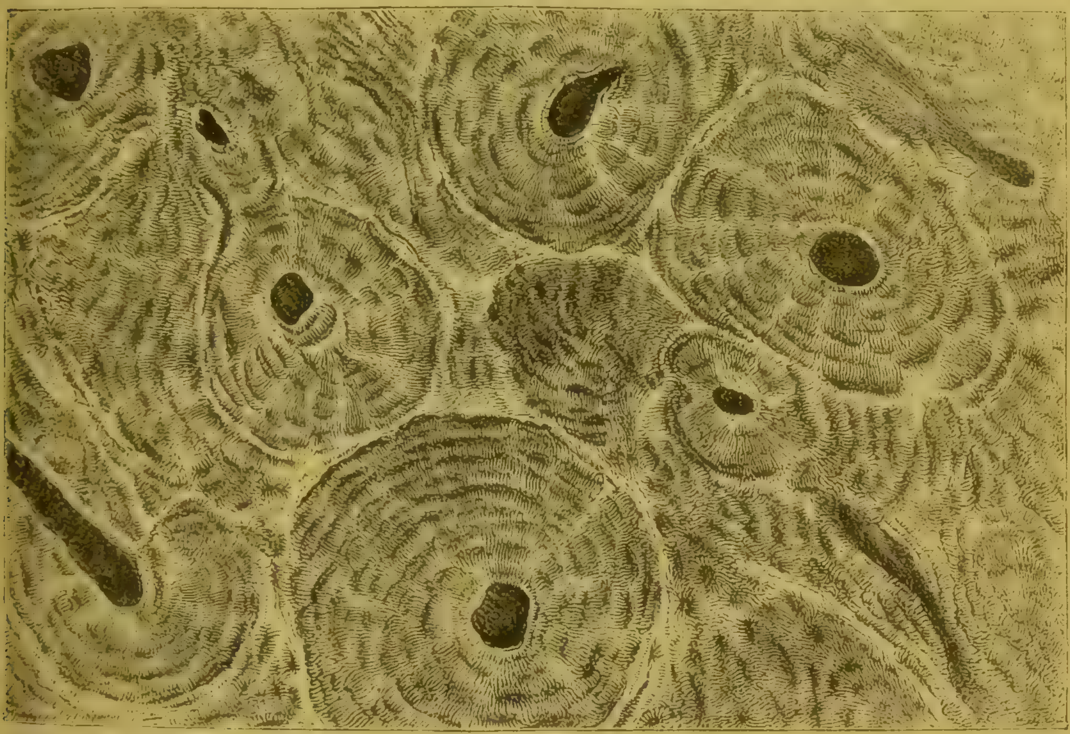
Fig. 46.

Vertical section of Tibia, showing the net-work of *Haversian Canals*.

* See "Princ. of Phys., Gen. and Comp.," § 320 *b*, et seq.

(Fig. 47); these circles are marked by a series of stellated points; and when the latter are magnified still more highly (Fig. 48), they are seen to be cavities or *lacunæ* of a peculiar form, which seems characteristic of Bone. They are usually oval or lenticular in form; and are so placed, that one of their largest surfaces is turned *from*, and the other *towards*, the Haver-

Fig. 47.



Portion of Transverse Section of *Human Clavicle*, showing the orifices of the Haversian canals, and the concentric arrangement of the laminæ of bony matter, and of the lacunæ, around them. Magnified 85 diameters.

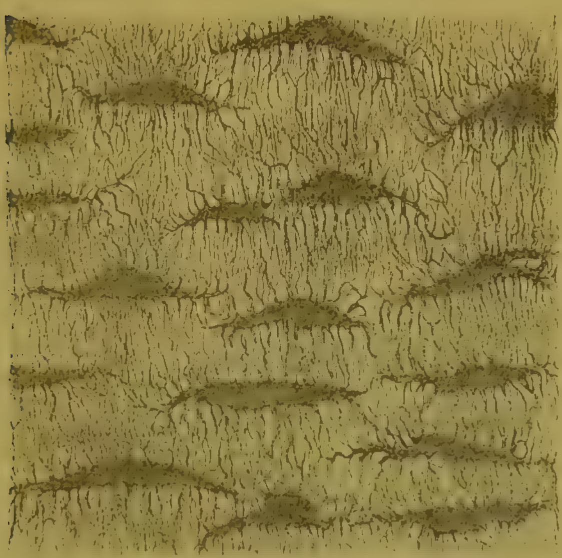
sian canal. Their long diameter in Man is commonly from 1-2400th to 1-1600th of an inch; their short diameter is about one-third, and their thickness about one-sixth, of their length.—It has been shown by Mr. J. Quekett,* that there are differences in the form and size of the lacunæ, in the several classes of Vertebrated animals, sufficiently characteristic to allow of the assignment of minute fragments of bone, with the aid of the microscope, to their proper group.

258. From all parts of the *lacunæ*, but especially from their two largest surfaces, proceed a large number of minute *canaliculi*, which traverse the substance of the bone, and communicate irregularly with one another (Fig. 48). Their direction, however, possesses a certain degree of determinateness; for those passing off from the inner surface converge towards the Haversian canal; whilst those passing off from the outer surface diverge in the contrary direction, so as to meet and inosculate with those proceeding inwards from the lacunæ of the next annulus. In this manner, a communication is kept up between the Haversian canal, and the most external of its concentric lamellæ of bone. It is not to be imagined, however, that *blood* can be conveyed by these canaliculi, their size being far too small; for their diameter, at their largest part, is estimated at

* "Transactions of the Microscopical Society," vol. ii. See also "Princ. of Phys., Gen. and Comp.," § 202.

from 1-14,000th to 1-20,000th of an inch, whilst that of the smaller branches is from 1-40,000th to 1-60,000th of an inch; so that the blood-corpuscles could not possibly enter them. But it may be surmised that they draw fluid from the nearest blood-vessels, and thus keep up a sort of circulation through the osseous substance, which may contribute to its growth, and may keep it in a state fit for repairing itself, when injured by disease or violence.*

Fig. 48.



Portion of a transverse section of the *Human Clavicle*, more highly magnified, to show the lacunæ and canaliculi.

259. Although a large quantity of blood is sent to Bone, the vessels do not penetrate its minute parts; being confined to the medullary cavity, and to the Haversian canals and the cancelli, which are prolongations of it. The substance of the Bone, therefore, is really as non-vascular as that of Cartilage; the only difference being, that it is channelled-out by more numerous inflections of the external surface, and that the vessels are thus brought into nearer proximity with its several parts. The delicate osseous lamellæ, which form the walls of the cancelli, and of the large 'cells' excavated in some of the cranial bones, have a structure precisely analogous to that of the cylindrical laminæ surrounding the Haversian canals of the long bones; and derive their nourishment from the vascular membrane covering their surface, through the medium of a similar set of lacunæ and canaliculi. They do not themselves contain Haversian canals or cancelli; because no part of their substance is far removed from a vascular membrane.—The cylindrical rods, that make up the hollow shaft of a long bone, are connected together by solid osseous substance, which is composed of lamellæ running parallel to the external surface of the bone; and these seem to derive their nutriment either from the periosteum, or from the membrane lining the central medullary cavity; according as they are nearest to one or to the other.—The membranous lining of the canals of Bone appears to be supplied with lymphatics, and also with nerves;

* The lacunæ and canaliculi of Bone were formerly supposed, on account of the dark aspect they exhibit under the Microscope, when viewed as transparent objects, and their white appearance when viewed by reflected light, to be filled with opaque matter: but the former is common to all cavities excavated in a highly-refracting substance (being shown by a bubble of air in water), and ceases when a very thin section of Bone is examined, especially if it have been placed in canada balsam; and the latter seems due to some peculiar state of the earthy deposit immediately surrounding the cavities, as it may be removed by the agency of an acid. In the bones of Mummies, these cavities are found to be filled with a waxen material; whilst in those which have lain in bogs, they are rendered peculiarly distinct by the infiltration of some of the surrounding black matter; and it is not difficult to make them imbibe liquids, even whilst they are under observation beneath the Microscope.

but with both in a very limited amount. The periosteum seems to be scarcely (if at all) sensible in the state of health, although painfully so when inflamed; and the same may be said of the membrane lining the Haversian canals and cancelli. The membrane lining the central medullary cavity, however, is more sensitive; since unequivocal signs of pain are manifested by an animal, when, a bone having been sawn across, a probe is passed up the cavity, or an acrid fluid is injected into it.

260. When a Bone is subjected to the action of dilute nitric or muriatic acid, which dissolves away the calcareous matter, a substance is left which possesses considerable tenacity, but which is at the same time very flexible. This is commonly termed Cartilage; but the name is inappropriate, since it has neither the structure nor the chemical composition of that tissue. The animal basis of Bone is not *chondrin*, the characteristic principle of Cartilage (§ 34); but *glutin*, the organic component of the White Fibrous tissue (§ 33). When examined microscopically, it does not exhibit any cartilage-cells, but presents the laminated texture of the original bone; and the lacunæ are still apparent, although their canaliculi cannot be readily traced. When a very thin lamella is peeled off the surface of the bone, it is found to have a distinctly fibrous structure; being composed, as was first pointed out by Dr. Sharpey,* of fibres in all essential respects resembling those of the White Fibrous tissue, which decussate one another obliquely, so as to form an exceedingly fine network, apparently adhering to each other at the points of intersection. The minute apertures between the reticulated fibres seem to give passage to the canaliculi.—If very thin sections of unaltered Bone, however, be examined with a high power, the solid portion lying between the lacunæ and the canaliculi presents somewhat of a granular appearance; the granules, as stated by Mr. Tomes,† are often distinctly visible without any artificial preparation, in the substance of the delicate spicules of the cancelli, when they are viewed with a high power; and are made very evident by prolonged boiling in a Papin's digester. They vary in diameter from 1-6000th to 1-14,000th of an inch; their shape is oval or oblong, often angular; and they cohere firmly together, possibly by the medium of some different material. Their own substance appears to be perfectly homogeneous; but it is made up of several components, as is demonstrated by Chemical analysis. It appears certain, however, that the mineral matters must be intimately united with the organized tissue, and not merely deposited in its interstices; since no distinction can be seen between them, even under the highest magnifying powers.

261. When the Calcareous matter of Bone has been removed by the action of an acid, the Animal substance which remains is almost entirely dissolved by a short boiling in water; yielding to it a large quantity of Glutin. This, indeed, may be obtained, by long boiling under pressure, from previously-unaltered Bone; and the calcareous matter is then left almost pure. The Lime of bones is, for the most part, in the state of Phosphate (§ 76); but a certain proportion of Carbonate

* See his excellent account of the structure and development of Bone, in his Introduction to "Quain's Elements of Anatomy," 5th edit. p. cxlii.

† Todd and Bowman's "Physiological Anatomy," p. 108, and "Cyclopædia of Anatomy and Physiology," art. 'Osseous Tissue.'

is always present. The following are the results of some of the most recent and careful analyses of Human Bone, by Marchand and Lehmann: those of the former were made on the compact substance of the femur of a man aged 30; and those of the latter on the long bones of the arm and leg of a man of 40 years of age.

| | Marchand. | Lehmann. |
|---|---|---|
| *Organic matter.* | | |
| Cartilage insoluble in hydrochloric acid | 27·23 | 32·56 |
| Cartilage soluble in hydrochloric acid | 5·02 | |
| Vessels | 1·01 | |
| *Inorganic matter.* | | |
| Phosphate of lime | 52·26 | 54·61 |
| Fluoride of calcium | 1·00 | |
| Carbonate of lime | 10·21 | 9·41 |
| Phosphate of magnesia | 1·05 | 1·07 |
| Soda | ·92 | 1·11 |
| Chloride of sodium | 0·25 | 0·38 |
| Oxides of iron and manganese, and loss | 1·05 | ·86 |
| | 100·00 | 100·00 |

According to Dr. Stark,* the relative proportions of cartilaginous and earthy matter, in the bones of different animals, in the bones of the same animals at different ages, and in the different bones of the same body, never depart widely from the preceding standard; the amount of earthy matter being always found to be just double that of the cartilaginous basis, when the bones have been carefully freed from oily matter, and completely dried, previously to the analysis. The hardness of bone, he maintains, does not at all depend upon the presence of an unusually large proportion of earthy matter; nor does their increased flexibility and transparency indicate a deficiency of the mineral ingredients: for the transparent readily-cut bones of Fish contain the same amount of earthy matter, in proportion to their gelatinous basis, as do the dense ivory-like leg-bones of the Deer or Sheep. The same holds good of the bones even of the so-called Cartilaginous Fish. The difference appears to depend upon the molecular arrangement of the ultimate particles; and especially, it seems likely, upon the relative amount of water which the bones contain.

262. Probably the most exact and comprehensive analyses yet made of Bone, are those of Von Bibra;† whose laborious investigations may be said to have almost exhausted the subject. The following table shows the relative proportions of the principal ingredients, in some of the principal bones of a woman aged 25 years.

| *Organic matter.* | Femur. | Occipital bone. | Scapula. | Rib. | Os innominatum. | Vertebra. | Sternum. |
|---|---|---|---|---|---|---|---|
| Cartilage | 29·54 | 29·87 | 32·90 | 33·06 | 38·26 | 43·44 | 46·57 |
| Fat | 1·82 | 1·40 | 1·73 | 2·37 | 1·77 | 2·31 | 2·00 |
| *Inorganic matter.* | | | | | | | |
| Phosphate of lime with a little fluoride of calcium | 57·42 | 57·66 | 54·75 | 52·91 | 49·72 | 44·28 | 42·63 |
| Carbonate of lime | 8·92 | 8·75 | 8·58 | 8·66 | 8·08 | 8·00 | 7·19 |
| Phosphate of magnesia | 1·70 | 1·69 | 1·53 | 1·40 | 1·57 | 1·44 | 1·11 |
| Soluble salts | 0·60 | 0·63 | 0·51 | 0·60 | 0·60 | 0·53 | 0·50 |
| | 100·00 | 100·00 | 100·00 | 100·00 | 100·00 | 100·00 | 100·00 |

* "Edinb. Med. and Surg. Journal," April, 1845.

† "Chemische Untersuchungen über die Knochen und Zähne des Menschen, und der Wirbelthiere."

The analyses of the long bones of the arm and leg correspond closely with that of the femur; but we observe that the proportions of ingredients in the more spongy bones are widely different. It is difficult, however, to say how far this variation is due to a difference in the proportions of gelatin and earthy matter, in the actual osseous substance; or how far it may be accounted-for by the presence of an increased proportion of membrane, forming the lining of the cancelli.—The same uncertainty must attend the explanation of the differences that present themselves at different ages; as shown in the following table, which gives a series of comparative analyses of the long bones, generally the femur.

| | Fœtus 6 months. | Fœtus 7 months. | Child 2 months. | Child 5 years. | Man 25 years. | Woman 62 years. |
|---|---|---|---|---|---|---|
| *Organic matter.* | | | | | | |
| Cartilage . . . . . | 40·38 | 34·18 | 33·86 | 31·28 | 29·70 | 28·03 |
| Fat . . . . . . | a trace | 0·63 | 0·82 | 0·92 | 1·33 | 2·15 |
| *Inorganic matter.* | | | | | | |
| Phosphate of lime with a little fluoride of calcium . . . | 53·46 | 57·63 | 57·54 | 59·96 | 59·63 | 63·17 |
| Carbonate of lime . . | 3·06 | 5·86 | 6·02 | 5·91 | 7·33 | 4·46 |
| Phosphate of magnesia . . | 2·10 | 1·10 | 1·03 | 1·24 | 1·32 | 1·29 |
| Soluble salts . . . | 1·00 | 0·60 | 0·73 | 0·69 | 0·69 | 0·90 |
| | 100·00 | 100·00 | 100·00 | 100·00 | 100·00 | 100·00 |

From this it will be seen, that there is a gradual diminution in the proportion of animal matter, through life; and a corresponding increase in the proportion of the earthy components. But this is not nearly so great as is usually supposed; and the greater solidity of the bones of old persons is doubtless owing chiefly to the fact, that their cavities are progressively contracted, by the addition of new bony matter (§ 265).

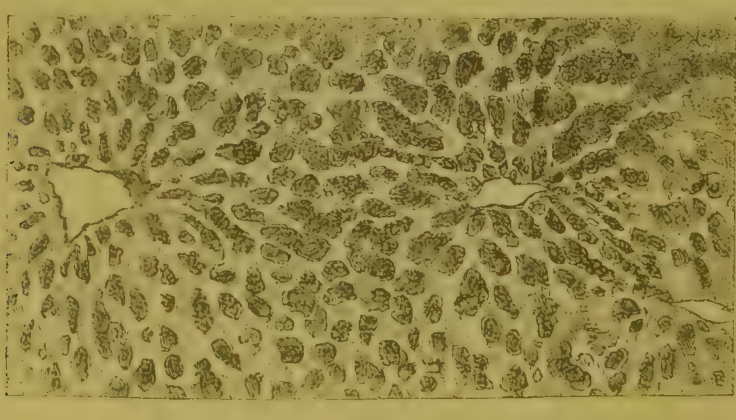
263. The first *Development* of Bone may take place in the substance, either of Membrane, or of Cartilage.* The tabular bones forming the roof of the cranium afford a good example of the first, or *intra-membranous* form of Ossification; for their place is but in part pre-occupied by cartilage, only a membrane being elsewhere interposed between the dura mater and the integuments. This membrane is chiefly composed of fibrous fasciculi, corresponding with those of the white fibrous tissues; but amongst these are seen numerous cells, some about the size of blood-discs, but others two or three times larger, containing granular matter; and a soft amorphous or faintly-granular matter is also found interposed amidst the fibres and cells. In certain parts, the fibres predominate; and in others, the cells. The process of ossification here seems at first to consist in the consolidation of the fibres by earthy matter; for the first bony deposit consists of an irregular reticulation, very loose and open towards its edges, where it frequently presents itself in the form of distinct spicula, which are continuous with fasciculi of fibres in the surrounding membrane. The limits of the calcifying deposit may be traced by the opaque and granular character of the parts affected by it;

* In recent times, the development of Bone from Cartilage has received almost exclusive attention; but the older opinion, that Bone is often developed in Membrane, has been lately brought again into notice by Dr. Sharpey (Op. cit. p. cxlviii. et seq.), who has demonstrated its truth by Microscopic research. The statements in the text, upon this part of the subject, are derived from Dr. Sharpey's observations, which the Author has himself confirmed.

and it gradually extends itself, involving more and more of the surrounding membrane, until the foundation is laid for the entire bone. Everywhere, the part most recently formed consists of a very open reticulation of fibro-calcareous spicula; whilst the older part is rendered harder and more compact, by the increase in the number of these spicula, and perhaps also by the calcification of the intervening cells. As the process advances, and the plate of bone thickens, a series of grooves or furrows, radiating from the ossifying centre, are found upon its surface; and these, by a further increase in thickness, occasioned by a deposit of ossific matter all around them, are gradually converted into closed canals (the Haversian), which contain blood-vessels, supported by processes of the investing membrane. Further deposits subsequently take place in the interior of these canals; which thus gradually produce a diminution of their calibre, and a consolidation of the bone; and in this manner its two surfaces acquire their peculiar density, whilst the intervening layer, or 'diploë,' retains a character more resembling that of the original osseous reticulation.—The mode in which the peculiar lacunæ and canaliculi are formed, in the concentric layers around the Haversian canals, probably corresponds with that in which they are generated in the *intra-cartilaginous* form of ossification, to which we shall next proceed.

264. In a very large proportion of the skeleton, the appearance of the Bones is preceded by that of Cartilages; which serve (so to speak) as the moulds for their formation, and which also seem destined to afford a certain degree of support to the surrounding soft parts, until the production of bone has taken place. The *temporary* Cartilages differ in no essential particular of structure or composition, from the *permanent.* They present the same irregular scattering of cells through a homogeneous intercellular substance; and there is the same absence of any vascularity in the cartilaginous tissue itself. In all considerable masses, however, we find a coarse network of canals, lined by an extension of the perichondrium or investing membrane; and these canals, which may be regarded as so many involutions of the external surface, allow the vessels to come into nearer relation with the interior parts of the cartilaginous

Fig. 49.

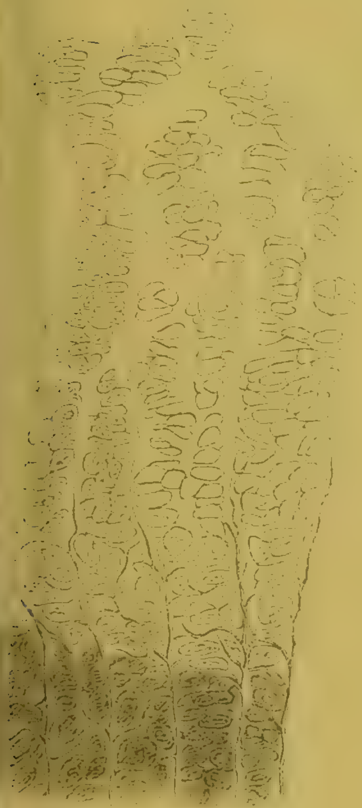


Transverse section of *Cartilage* close to the plane of Ossification.

structure, than they would otherwise do. They are especially developed at certain points, which are to be the centres of the ossifying process; and it is always observable, that the vascularity is greatest at the

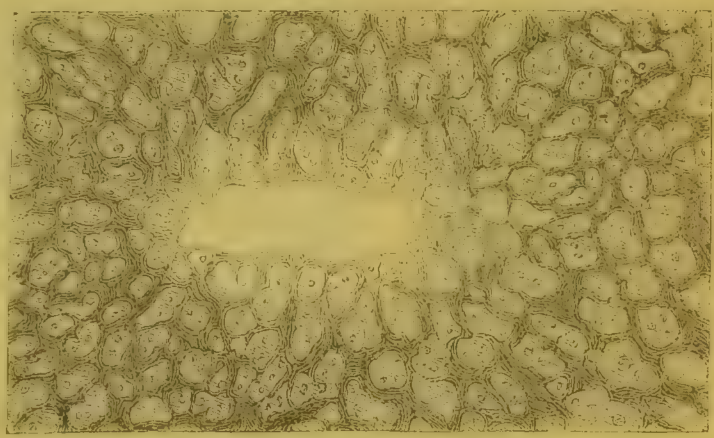
zone in which the conversion of cartilage into bone is actually taking place, and that the cartilage-cells are there arranged in a somewhat radiating manner around them (Fig. 49). During the extension of the vascular canals into the Cartilaginous matrix, certain changes are taking place in the substance of the latter, which are preparatory to its conversion into Bone. Instead of single isolated cells, or groups of two, three, or four, such as we have seen to be characteristic of ordinary Cartilage (Fig. 41), we find, as we approach the plane of ossification in a vertical section, clusters made up of a larger number arranged in a linear manner (Fig 50); which seem to be formed by a continuance of the same

FIG. 50.



Vertical section of *Cartilage at the seat of Ossification;* the clusters of cells are arranged in columns, the intercellular spaces between them being 1-3250th of an inch in breadth. At the lower end of the figure, osseous fibres are seen occupying the intercellular spaces, at first bounding the clusters laterally, then splitting them longitudinally and encircling each separate cell. The greater opacity of this portion is due to a threefold cause; the increase of osseous fibres, the opacity of the contents of the cells, and the multiplication of oil-globules.

FIG. 51.

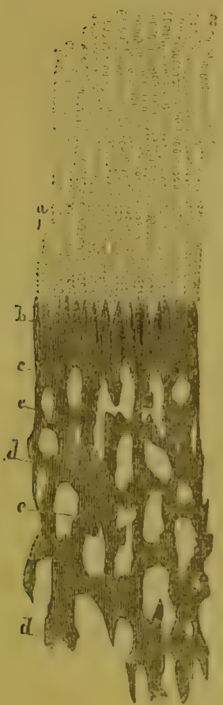


First *Osseous network* formed in the intercellular substance of Cartilage, around a vascular canal, as in Fig. 49.

multiplying process as that formerly described (§ 104). And when we pass still nearer, we see that these clusters are composed of a yet greater number of cells, which are arranged in long rows, whose direction corresponds to the longitudinal axis of the bone: these clusters are still separated by intercellular substance; and it is in this, that the ossific matter is first deposited. If we separate the cartilaginous and the osseous substance at this stage of the process, we find that the ends of the rows of cartilage cells are received into deep narrow cups of bone, formed by the calcification of the intercellular substance between them (Fig. 51). Thus the Bone first formed in the cartilaginous matrix, is seen to consist of a series of lamellæ of a somewhat cylindrical form; inclosing oblong areolæ, or short tubular cavities, within which the piles of cartilage-cells yet lie: and it thus corresponds closely with the reticular structure, which first makes its appearance in the intra-membranous form of the process.—So far, it would appear that the blood-vessels are not directly concerned in the operation; for although they advance to the near neighbourhood of the first ossific deposit, they do not make their way into its substance, or even into the intervening areolæ.

265. This state of things, however, speedily gives place to another. On examining the subjacent portion, in which the ossification has advanced further, it is found that the original closed cavities have coalesced to a certain extent (probably by the absorption of their walls), both laterally and longitudinally; and that they now form a cancellated texture (Fig. 52, *d*), the areolæ of which (*e*, *e*) receive numerous blood-vessels, prolonged into them from the previously-ossified portion. The groups of cartilage-cells which originally occupied the cavities, are no longer seen; and their place is filled with a blastema, composed of cells containing a granular matter, and closely resembling those seen in the intra-membranous ossification, with a few fibres scattered amongst them. It is by a change in this blastema, that the walls of the cavities are gradually consolidated; new deposits of ossific matter being formed in their interior, which occasion the gradual contraction of the cavities, and give an increasing density to the bone. The cancellated structure, which remains for a time in the interior of the long bones, and which continues to occupy their extremities, represents the early condition of the ossifying substance, with very little change; whilst the cavities which have formed more regular communications with each other, and which have been gradually contracted by the subsequent deposit of concentric lamellæ, one within another, form the original Haversian canals. Thus we see that they all form one system in their origin; as they may be considered to do, notwithstanding the difference of their form, in the complete bone.

Fig. 52.



Vertical Section through the *Cartilage and incipient Bone* of the diaphysis of the Femur, in an Infant a fortnight old:—*a*, cartilage-cells arranged in longitudinal piles near the ossified surface; *b*, plane of ossification, the osseous matter inclosing the bases of the piles; *c*, close osseous network first formed; *d*, cancellated structure formed by the absorption of parts of this; *e*, its cancelli, filled with medulla.

266. The original osseous lamellæ, formed by the consolidation of the cartilaginous substance, are entirely composed of granular matter; and exhibit none of the lacunæ and canaliculi, which are commonly regarded as characteristic of Bone. These excavations present themselves, however, in all the subsequent deposits; and into the origin of these, we have now to inquire.—According to the views of Messrs. Todd and Bowman, and of Mr. Tomes (Op. cit.), the cells of the blastema fill themselves with ossific matter, except at the points occupied by the nuclei; at the same time, they become flattened against the walls of the canals, and their nuclei send out radiating prolongations; so that, when the calcification of the cell has been completed, a stellate cavity is left in the hard deposit, which is occupied by the granular matter of the nucleus. The centre of this cavity forms the *lacuna*, in which some traces of the original granular matter may frequently be found remaining; whilst its prolongations form the *canaliculi*, from which the nuclear matter seems afterwards to disappear altogether.—By Henle, again, it is considered that the lacuna is a cavity left in the centre of a cell, which has been partially filled up by the deposition of calcifying matter upon the internal surface of its wall; and

that the unequal deposit of this matter leaves passages, resembling those of the 'pore-cells' of plants, which constitute the canaliculi.—It is justly remarked, however, by Dr. Sharpey, that neither of these two views is reconcilable with the structure of ordinary sound bone: in which there is not only an absence of any vestiges of cell-boundaries, limiting the radiation of the canaliculi which issue from each lacuna; but it is constantly to be observed, that the canaliculi of one lacuna encroach upon the areæ traversed by those of the next. And it is considered by Dr. S., that the lacunæ and canaliculi are "little vacuities left in the tissue during the deposition of the reticular fibres, as open figures are left out in the weaving of some artificial fabrics; and thus that the apposition of the minute apertures existing between the reticulations of the lamellæ gives rise to the canaliculi. At the same time it seems not unlikely that a cell or a cell-nucleus may originally lie in the lacuna or central cavity, and perhaps determine the place of its formation." (Op. cit., p. clviii.) — The Author has been led, however, from his own observations, to consider, with Schwann, that each lacuna, with its system of radiating canaliculi, is one entire cell, resembling the pigment-cells of Batrachia (Fig. 66, *c*, *c*), which send out stellate prolongations that sometimes inosculate with each other; and to believe that these prolongations in their outward growth insinuate themselves through the areolæ of the fibrous basis, whilst it is undergoing calcification, after the manner in which the rootlets of plants extend themselves through the loosest parts of a dense soil. For he has traced all stages of gradation between the simple rounded cavities, whose correspondence in size and situation with the cells that are scattered in the midst of the consolidating blastema leaves scarcely any doubt of their identity with these, and the lenticular lacunæ with numbers of canaliculi proceeding from them.*—Whatever may be the precise mode of the production of the lacunæ and canaliculi, it may be considered as a well-established fact, that the production of the concentric layers of osseous substance within the Haversian canals takes place in a manner that more closely corresponds with the intra-membranous, than with the intra-cartilaginous form of osteogenesis; and that thus it is only with the very first stage of the process, that the cartilaginous matrix has any concern.†

267. In the formation of a long bone, we usually find one centre of ossification in the shaft, and one in each of the epiphyses; in the flat bones, there is one in the middle of the surface, and one in each of the principal processes. The ossification usually proceeds to a considerable extent, however, in the main centre, before it commences in the extremities or processes; and these remain distinct from the principal mass of the bone, long after this has acquired solidity. During the spread of the ossifying process, the cartilaginous matrix continues to grow, like cartilage in other parts; but after the bony deposit has pervaded its entire

* The independent observations of Dr. Leidy of Philadelphia precisely confirm those of the Author upon this point. (See the "Proceedings of the Philadelphia Academy of Natural Sciences," Nov. 1848). The various gradations of the calcifying process in a fibrous tissue may be very well seen in the ossified tendons of the legs of many Birds.

† The account recently given by Prof. Kölliker of the formation of the lacunæ, &c. is too much founded, as it appears to the Author, upon observations made upon an abnormal mode of it, which cannot be taken as the criterion of the healthy process. (See § 269). Some criticisms upon Prof. K.'s views will be found in the "Brit. and For. Med. Chir. Rev.," Jan. 1852.

substance, in the manner just described, a change takes place in the method adopted. The osseous laminæ, that subdivide the whole texture, are removed by absorption from the interior of the shaft, so as to leave the great central medullary cavity; whilst, on the other hand, they receive progressive additions in the external portion, which is thus gradually consolidated into the dense bone, that forms the hollow cylinder of the shaft. This consolidation is effected by the deposit of a series of concentric laminæ, one within another, on the lining of the Haversian canals. —The bone continues to increase in *diameter*, by the formation of new layers upon its exterior; and Dr. Sharpey has pointed out that these layers are formed, not (as usually stated) in a cartilaginous matrix, but in the substance of a *membrane* that intervenes between the proper periosteum and the surface of the bone, consisting of fibres and granular cells, and exactly resembling that in which the flat bones of the roof of the skull are developed. The basis of this sub-periosteal tissue has been shown by Scherer not to be chondrin, but glutin; consequently it has no title whatever to the designation of cartilage, which some have applied to it. The Haversian canals, too, of these new layers, are formed in the same manner as those of the tabular bones of the skull; the osseous matter being not only laid-on in strata parallel to the surface, but also being deposited around processes of the vascular membranous tissue, which extend obliquely from the surface into the substance of the shaft; the channels, in which these membranous processes lie, becoming narrowed by the deposition of concentric osseous laminæ, and at last remaining as the Haversian canals. Whilst this new deposition is taking place on the exterior of the shaft, absorption of the inner and older layers goes on; so that the central cavity is proportionably enlarged.—The increase of the bone in *length* appears due to the growth of the cartilage between the shaft and the epiphyses, so long as this remains unconsolidated by ossific deposit; and this state continues, until the bone has acquired nearly its full dimensions. What further increase it gains, seems chiefly if not entirely due to the progressive ossification of the articular cartilage covering the extremities; which progressively diminishes in thickness during the whole of life, and which in old age sometimes appears to have been almost completely converted into bone.

268. It thus appears that there is no true *interstitial* growth in Bone; that is, the parts, through which the ossific process has made its way, are incapable of any further extension than by addition to their *surface*. By the admirable system of prolongations, however, by which the vascular membrane is conveyed into its intimate substance, we find this method of superficial deposit adapted to the consolidation of parts which are at first sketched out (as it were) by a slight osseous reticulation; whilst by the facility with which the bony matter is absorbed in the internal part of the shaft, at the same time that it is being deposited on its exterior, the same effect is produced, as if the whole cylinder could enlarge uniformly by a proper interstitial growth, in the manner of the softer tissues.—Much of our information regarding the mode in which new osseous matter is deposited, is derived from observations made upon the bones of animals that have been fed with madder; for this colouring-matter, having a strong affinity for bone-earth, tinges all those parts which are in close relation with the vascular surfaces. In very young animals, a single day

serves to colour the entire substance of the bones; for there is in them no osseous matter far removed from a vascular surface. At a later period, however, the colouring matter is deposited less rapidly; and is found to be confined to the innermost of the concentric laminæ of bone surrounding each Haversian canal, showing that this is the last formed. When madder is given to a growing animal, the external portion of the shaft is first reddened; showing that the new formation takes place exclusively in that situation. And if, when time has been allowed for this part to become tinged, the administration of the madder be discontinued, and the animal be killed some weeks afterwards, the red stratum is surrounded by a colourless one of subsequent formation; whilst the colourless layer internal to the red one, and formed previously to it, is thinned by absorption from within. By alternately administering and withholding the madder, a succession of coloured and colourless cylinders may thus be formed in the shaft of a long bone; which present themselves as concentric rings in its transverse section.

269. The nature of the Ossifying process receives some additional light from the abnormal forms, in which it occasionally presents itself in Cartilages that are usually permanent; as well as in various Fibrous tissues, such as the coats of the arteries, fibrous and serous membranes, muscular substance, &c.; and also in the development of Tumours. In most of these cases, the ossific deposit may often be seen to take place, in the first instance, in the form of distinct granules, which gradually coalesce; or in the form of spicular fibres, to which additions are progressively made, until a solid mass is produced. This adventitious bone, however, almost invariably differs from true or normal bone, in the want of a regular Haversian system with concentric laminæ, and in the absence or imperfect production of the characteristic lacunæ and canaliculi. Irregular cavities, however, are scattered through them, which may in some degree answer the same purpose; and these, in osseous tumours which had originally a Cartilaginous basis, may often be plainly seen to be the persistent cartilage-cells, or the nuclei of cartilage-cells, the intervening substance having undergone calcification and gradually inclosed them. It is curious that in certain abnormal Cartilaginous growths, the nuclei have a stellate form, and the cartilage-cells become fused with the surrounding basis-substance; so that, when the latter is calcified, the enclosed stellate nuclei present a strong resemblance to the normal lacunæ and canaliculi of bone.* But it may be stated as a well-established fact, that calcified tissues having a more or less close resemblance to true Bone, may be produced in a great variety of modes; and no inference can be fairly drawn from such observations, therefore, in regard to the normal process of Osteogenesis. For Osseous tissue, though of a very imperfect kind, is often formed in the substance of Fibrous tumours, by the calcification of their organic base; and it is curious that this should usually contain a very large proportion of calcareous matter, as much as 81½ per cent having been found in a specimen transmitted to John Hunter as a calculus, and the proportion of carbonate of lime being much greater than in normal bone. Where perfected Osseous structure presents itself in a Tumour, it is usually as an outgrowth from true Bone. It is curious,

* See Mr. Paget's 'Lectures on Tumours,' in "Medical Gazette," Aug. 8, 1851.

however, that the osseous plates not unfrequently found in the dura mater, possess a structure (as pointed out by Mr. Tomes, loc. cit.) much more closely allied to that of true bone, than that which presents itself in most adventitious formations of this kind; and this seems related to the fact, that, in some of the lower Mammalia, especially of the Carnivorous order, certain parts of this membrane (the falx and tentorium) are normally ossified.

270. The *Regeneration* of Bone, after loss of its substance by disease or injury, is extremely complete; in fact, there is no other structure of so complex a nature, which is capable of being so thoroughly repaired. Much discussion has taken place, with respect to the degree in which the different membranous structures, that surround bone and penetrate its substance, contribute to its regeneration; but the fact seems to be, that any or *all* these membranes may contribute to the formation of new bone, in proportion to their vascularity,—the new structure, however, being most readily produced in continuity with the old. Thus, when a portion of the shaft of the bone is entirely removed, but the periosteum is left, the space is filled up with bony matter in the course of a few weeks; though, if the periosteum also be removed, the formation of new osseous matter will be confined to a small addition in a conical form to the two extremities, a large interspace being left between them. The production of new bony tissue, in this experiment, as in cases where the periosteum has been detached by disease and remains alive while the shaft dies, is in continuity with minute spicula of original bone, which still adhere to the membrane; and it is well known that, in comminuted fractures, every portion of the shattered bone, that remains connected with the vascular membranes, whether these be internal or external, becomes the centre of a new formation; the loss of substance being filled up the more rapidly, in proportion to the number of such centres.

271. The most extensive reparation is seen, when the shaft of a long bone is destroyed by disease. If violent inflammation occur in its tissue, the *death* of the fabric is frequently the consequence; apparently through the blocking-up of the canals with the products of inflammatory action, and the consequent cessation of the supply of nutriment. It is not often that the whole thickness of the bone becomes necrosed at once; more commonly this result is confined to its outer or to its inner layers. When this is the case, the new formation takes place from the part that remains sound; the external layers, which receive their vascular supply from the periosteum, and from the Haversian canals continued inwards from it, throwing out new matter on their interior, which is gradually converted into bone; whilst the internal layers, if *they* should be the parts remaining uninjured, do the same on their exterior, deriving their materials from the medullary membrane, and from its prolongations into their Haversian canals. But it sometimes happens that the whole shaft suffers necrosis; and as the medullary membrane and the entire Haversian system have lost their vitality, reparation can then only take place from the splinters of bone which may remain attached to the periosteum, and from the living bone at the two extremities. This is consequently a very slow process; more especially as the epiphyses, having been originally formed as distinct parts from the shaft, do not seem able to contribute much to the regeneration of the latter.

272. When the shaft of a long bone of a dog, rabbit, or bird has been fractured through, and the extremities have been brought evenly together, it is found that the new matter first ossified is that which occupies the central portion of the deposit, and which thus connects the medullary cavities of the broken ends, forming a kind of plug that enters each. This was termed by Dupuytren, by whom it was first distinctly described, the *provisional callus;* and it serves to hold the bones together during the formation of the *permanent callus*, which passes directly between the fractured surfaces, and which usually requires a much longer time for its production. After this more direct union has been established, the provisional callus is gradually absorbed, and the continuity of the medullary canal is thus restored, in the manner in which it was first established. These statements do not apply to Man, however, without great modification. For, as Mr. Paget has pointed out,* it is very rare to find a true provisional callus uniting the fractured ends of a human bone; and since, where this does present itself, as in the ribs, and occasionally in the clavicle, the two broken ends are in a state of continual movement, we are probably to attribute its absence in other cases, to the maintenance of quietude and more perfect apposition. Mr. Gulliver has remarked † that, when the broken portions of bone form an angle, there is quite a distinct centre of ossification in the new matter, from which that portion of it is ossified, that lies between the sides of the angle; thus forming what has been termed an *accidental callus*, and giving support to the two portions of the shaft, in a situation which is exactly that of the greatest mechanical advantage. Though for some time quite unconnected with the old bone, it soon becomes united to the regular callus. This instance proves, that continuity with previously-formed bone is not absolutely requisite for the production of new osseous structure; although the process is decidedly favoured thereby.

273. The production of new Osseous tissue, after disease or injury, seems to take place upon a plan essentially the same as its original formation. A plastic or organizable exudation is first poured out from the neighbouring blood-vessels; and this nucleated blastema may itself, according to Mr. Paget's observations,‡ undergo conversion into bone, without any intermediate stage;—a finely-granular osseous deposit taking place in the blastema, and gradually accumulating so as to form the delicate yet dense lamellæ of fine cancellous tissue; and the nuclei apparently giving origin to the osseous lacunæ and canaliculi. But where this simplest form of the process does not take place, the nucleated blastema gives origin either to a cartilaginous or to a fibrous structure, or to a combination of both. The former seems more common among the lower animals, especially when they are young, than it is in Man; when it occurs, the cartilage is converted into bone after the usual manner. In older animals, however, the new structure appears to be rather of a fibrous character; and the ossifying process would therefore correspond rather with that, by which the normal increase of their bones is effected. Mr. Tomes states § that he has examined various cases of fracture of the neck or shaft of the femur,

* 'Lectures on Repair and Reproduction,' in "Medical Gazette," July 20, 1849, p. 116.

† "Edinb. Med. and Surg. Journal," vol. xlvi. p. 313.

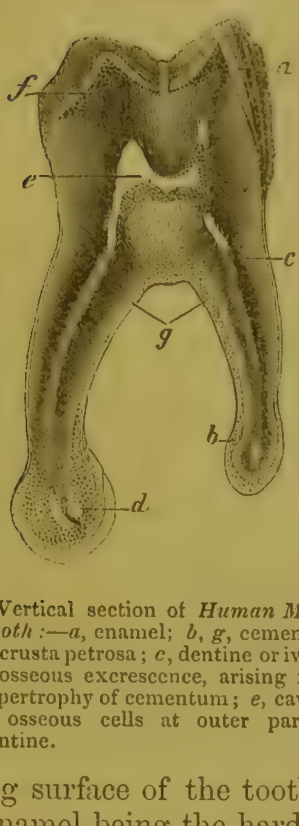
‡ Op. cit., pp. 120, 121.

§ "Cyclopædia of Anatomy and Physiology," vol. iii. p. 857.

in which union has not been effected, in consequence of the patient's advanced age; and that he found in these no intervening cartilage, and but a scanty amount of condensed areolar tissue. In this latter, traces of an attempt at repair may be generally found, in the presence of osseous matter in granules or granular masses; but in these there is no arrangement of tubes or bone-cells of definite character; indeed, such osseous masses are generally small, and are deficient in density, owing to the want of union between the individual granules.

274. The *Teeth* are nearly allied to Bone in structure; and in some of the lower Vertebrata, there is an actual continuity between the bone of the jaw, and the teeth projecting from it, notwithstanding that the latter form part of the *dermal* skeleton, whilst the former belongs to the *neural* or internal. In Man and the higher animals, however, there is an obvious difference in their structure, as in their mode of development. These subjects have lately received much attention; and the practical importance of an acquaintance with them, renders it desirable that they should be here treated somewhat fully.—The Teeth of Man, and of most of the higher animals, are composed of three very different substances; *Dentine* (known as *ivory* in the tusk of the Elephant), *Enamel*, and *Cementum* or *Crusta Petrosa.* These are disposed in various methods, according to the purpose which the Tooth is to serve: in Man, the whole of the crown of the tooth is covered with Enamel (Fig. 53, *a*); its root or fang is covered with Cementum (*b*, *g*), whilst the substance or body of the tooth is composed of Dentine (*c*). In the molar Teeth of many Herbivorous animals, however, the Enamel and Cementum form vertical plates, which alternate with plates of Dentine, and present their edges at the grinding surface of the tooth; and the unequal *wear* of these substances,—the Enamel being the hardest, and the Cementum the softest,—occasions this surface to be always kept rough.

FIG. 53.



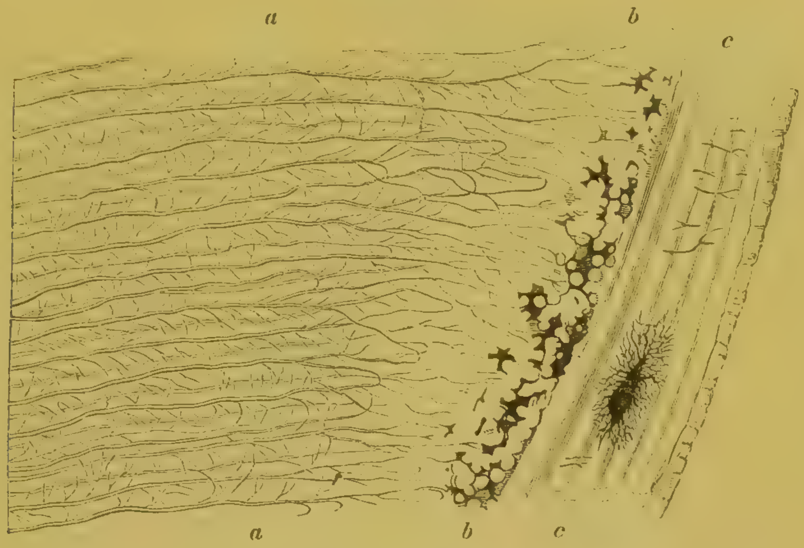

Vertical section of *Human Molar Tooth*:—*a*, enamel; *b*, *g*, cementum or crusta petrosa; *c*, dentine or ivory; *d*, osseous excrescence, arising from hypertrophy of cementum; *e*, cavity; *f*, osseous cells at outer part of dentine.

275. The *Dentine** consists of a firm substance, in which mineral matter largely predominates, though to a less degree than in the enamel. It is traversed by a vast number of very fine cylindrical branching wavy tubuli; which commence at the pulp-cavity (on whose wall their openings may be seen), and radiate towards the surface (Fig. 54, *a a*). In their course outwards, the tubuli occasionally divide dichotomously; and they frequently give off minute branches, which again send off smaller ones. These branchings are more frequent, the nearer the tubes approach the exterior of the dentine; and indeed it is only in the immediate neighbourhood of the enamel, that the dentinal tubes of the crown of the

* A structure exactly resembling Dentine has been found by the Author in the shell of the Crab, especially at the tips of the claws; and a less regular structure of the same kind in the shells of many Mollusca. ("Princ. of Phys., Gen. and Comp.," §§ 197, 199.)

human tooth usually begin to ramify, although those of the neck and fang give off branches about the middle of their course. The terminal branches, on their arrival at the line of junction between the dentine and enamel, sometimes recurve and anastomose with contiguous tubes, some-

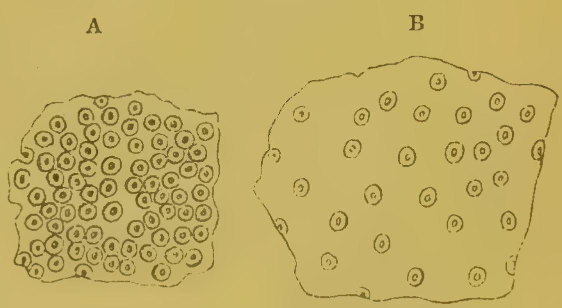
Fig. 54.




Section through the fang of a *Molar Tooth*:—*a*, *a*, dentine traversed by its tubuli; *b*, *b*, nodular layer; *c*, *c*, cementum.

mes pass across the line of junction and extend themselves for a short stance into the enamel (as first noticed by Mr. Tomes),* and sometimes ıd in a fine point or in a rounded dilatation. In the fang of the tooth, ıere is a much more frequent anastomosis among the tubuli; and of eir terminal branches, some lose themselves in their intertubular tissue, hers dilate into radiating cells not unlike those of the cementum, others astomose and form loops with the branches of adjacent tubes, whilst hers pass into the interspaces that exist among the large granules that m the outer surface of the dentine of the fang (Fig. 54, *b b*), and some these may even extend themlves into the cementum and mmunicate with its radiating lls. When the dentinal tubuli e examined in transverse secn (Fig. 55), the aperture of ch is seen to be surrounded by annulus, which separates its rietes from the intertubular sue; and it can be further seen tter in transverse than in lonudinal sections, that the disıces of the tubuli from each ıer vary greatly; the tubuli being closest, and the intertubular tissue ısequently the smallest in amount, in the crown of the tooth (A); ilst in the dentine of the fang the intertubular tissue forms the larger

Fig. 55.

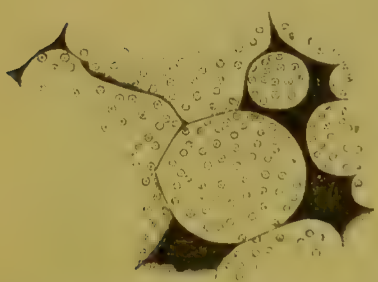



Transverse sections of *Dentine*; A, from the crown; B, from the fang; showing the orifices of the tubes, and the thickness of their walls.

* See his "Lectures on Dental Physiology and Surgery," p. 35. Mr. Tomes has since wn that the passage of the dentinal tubes into the Enamel, in large numbers, and for a siderable distance, is a distinctive character of the teeth of Marsupialia. "Philos. nsact.," 1849.

element (B). The internal diameter of the tubuli in their largest part averages about 1-10,000th of an inch, but when their parietes are included, it measures about 3-10,000ths; their smallest branches are immeasurably fine. The intertubular tissue of dentine, as of bone, is affirmed by Mr. Tomes to be granular throughout; the granules being nearly spherical, and measuring from 1 to 3-10,000ths. Near the surface of the dentine in the fang, and occasionally in other parts of the tooth, it presents the appearance of an aggregation of nodular concretions, with irregular interspaces between them (Fig. 54, *b b*); each of these, when divided transversely and highly magnified, is seen to be traversed by several dentinal tubes (Fig. 56). In other parts of the tooth, it not unfrequently happens that the dentinal substance is traversed by lines which divide it into more or less regular polygonal areæ; and this appearance, which is normal in the teeth of many of the lower animals, is considered by Prof. Owen as indicative of the persistence of the boundaries of the original cells of the pulp. A more satisfactory explanation of it is afforded, however, by Mr. Tomes's researches on the development of dentine (§ 213).—The Dentinal tubuli are far too minute to receive blood; but it may be surmised that, like the canaliculi of bone, they absorb matter from the vascular lining of the pulp-cavity, which aids in the nutrition of the tooth. Although, when once fully formed, the Tooth undergoes little or no change, there is evidence that it possesses a certain power of repairing the effects of disease; a new layer of hard matter being sometimes thrown out on a surface, which has been laid bare by Caries. It has been found, too, that the Dentine is sometimes tinged by colouring matters contained in the blood. This is most evident, when a young animal is fed upon madder, during the period of the formation of the tooth; but even in an adult, some tinge will result from a prolonged use of this substance; and it has been noticed that the teeth of persons, who have long suffered from Jaundice, sometimes acquire a tinge of bile.—The pulp-cavity is sometimes the seat of a secondary development of dentinal substance, by which its cavity is greatly contracted, or even obliterated. This is seen especially in the teeth of old persons, or in those which have been much worn; and also in those that are the subjects of caries, a layer of 'secondary dentine' being formed between the soft pulp, and the spot towards which the disease is advancing. This 'secondary' dentine is not so regular in its structure as the 'primary,' and more resembles that of the lower animals; for it is usually traversed by 'vascular canals' proceeding from the pulp-cavity, and the tubuli radiate from these, instead of from one common centre. Moreover, the presence of stellate lacunæ, resembling those of bone, is much more common in this substance than in true dentine; so that, both in the presence of the vascular canals which represent the Haversian, and also in its own texture, this substance may be considered as intermediate between Dentine and Bone.

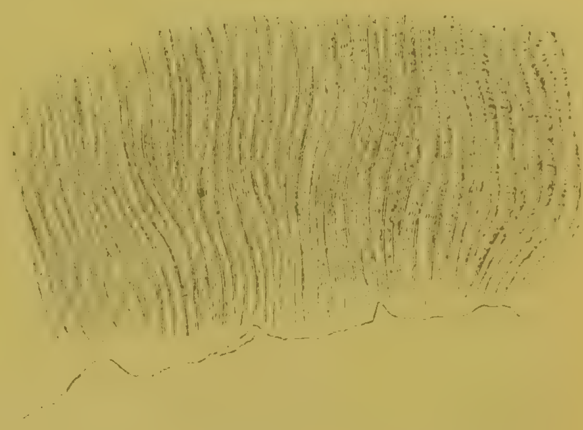
FIG. 56.



Portion of the nodular layer of the *Dentine of the fang*, more highly magnified.

276. The *Enamel* (Fig. 57) is composed of solid prisms or fibres (Fig. 58, B), from about 1-5600th to 1-3300th of an inch in diameter, arranged side by side, and closely adherent to each other; their direction is for the most part vertical to that of the dentinal surface on which they rest, so that their length corresponds with the thickness of the layer which they form; and the two surfaces of this layer present the ends of the prisms, which are usually more or less regularly hexagonal (Fig. 58, A). The course of these prisms is generally wavy (Fig. 57), but their curves are for the most part parallel to each other; not unfrequently, however, the curves separate from each other, or

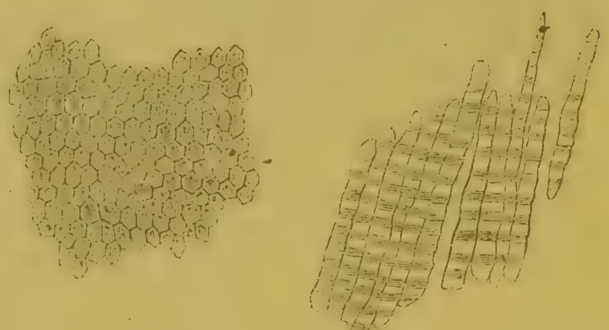
Fig. 57.



Vertical section of the *Enamel* of the Human Molar Tooth.

even decussate, the intervening spaces being then filled-in with shorter fibres. The enamel-prisms are usually marked by transverse striæ (Figs. 57, 58 B), the distance of which is about equal to the diameter of the fibre; these appear to be indications of the partitions between the longitudinally-joined cells, by whose coalescence each enamel-prism is originally formed (§ 280). In the perfect state, the Enamel contains but an extremely minute quantity of animal matter; but if a young tooth be examined, it is found that, after the calcareous matter of the tooth has been dissolved away by an acid, there remains a set of distinct prismatic cells, which formed (as it were)

Fig. 58.




A, Transverse section of *Enamel*, showing the hexagonal form of its prisms; B, separated prisms.

the moulds in which the mineral substance was deposited.* The Enamel, when once formed, appears to undergo scarcely any further change, and it possesses no power of self-regeneration after loss of substance by injury or disease.

277. The *Cementum* or *Crusta Petrosa* corresponds in all essential particulars with Bone, possessing its characteristic lacunæ, and being also traversed by vascular medullary canals, which pass into it from its external surface, wherever it occurs in sufficient thickness (as in the exterior of the tooth of the extinct Megatherium, and in the thick plates interposed within the islets of Enamel in the teeth of Ruminants, Rodents, &c.); in Man, however, in whose teeth the Cementum is very

* The Author has discovered a structure precisely resembling this, in the shells of many Mollusca. See "Reports of the British Association" for 1844 and 1847.

thin, such vascular canals do not usually exist, though Mr. Tomes states (Op. cit., p. 57) that he has occasionally met with them. The Cementum was formerly supposed to be restricted to the compound teeth of Herbivorous animals; and its presence in the simple teeth of Man and the Carnivora can be shown only by the application of the Microscope. In the latter it forms a layer, which invests the fang, and which decreases in thickness as it approaches the crown of the tooth (Fig. 53, *b*, *g*); at the time of the first emersion of the tooth, it covers the crown also with a very thin lamina, which is speedily worn away by use; on the other hand, its thickness around the apex of the fang often undergoes a subsequent increase, especially when chronic inflammation and thickening take place in the membranous contents of the socket (*d*).

278. The following are the results of the most recent Chemical analyses of the component structures of Human Teeth:—*

*Incisors of Adult Man.*

| | Dentine. | Enamel. | Cementum. |
|---|---|---|---|
| Organic matter | 28·70 | 3·59 | 29·27 |
| Earthy matter | 71·30 | 96·41 | 70·73 |
| | 100·00 | 100·00 | 100·00 |

The proportion of these two components varies considerably in different species; thus the organic basis of the Elephant's tusk forms as much as 43 per cent. of the whole. It would seem even to vary considerably in different individuals of the same species; thus in the molar teeth of one man, Von Bibra found the organic matter to constitute as little as 21 per cent, whilst in another it was 28.—The following analyses afford a more particular view of the components of each substance :—

*Molars of Adult Man.*

| | Dentine. | Enamel. |
|---|---|---|
| Phosphate of Lime, with trace of fluate of lime | 66·72 | 89·82 |
| Carbonate of Lime | 3·36 | 4·37 |
| Phosphate of Magnesia | 1·08 | 1·34 |
| Other Salts | 0·83 | 0·88 |
| Chondrin (?) | 27·61 | 3·39 |
| Fat | 0·40 | 0·20 |
| | 100·00 | 100·00 |

*Incisors of Ox.*

| | Dentine. | Enamel. | Cementum. |
|---|---|---|---|
| Phosphate of Lime, with trace of fluate of lime | 59·57 | 81·86 | 58·73 |
| Carbonate of Lime | 7·00 | 9·33 | 7·22 |
| Phosphate of Magnesia | 0·99 | 1·20 | 0·99 |
| Salts | 0·91 | 0·93 | 0·82 |
| Chondrin (?) | 30·71 | 6·66 | 31·31 |
| Fat | 0·82 | 0·02 | 0·93 |
| | 100·00 | 100·00 | 100·00 |

279. The Dentine and its modifications, the Enamel, and the Cementum, originate in three distinct structures; which may be termed respectively, the dentinal-pulp, the enamel-pulp, and the capsular or cemental-pulp; the whole forming the 'matrix' from which the entire tooth is evolved. —The Dentinal pulp is always the first-developed part of the matrix; and it makes its appearance in the form of a papilla, budding-out from the

* See Von Bibra's "Chemische Untersuchungen über die Knochen und Zähne."

free surface of a fold or groove of the mucous membrane of the mouth. The substance of this papilla at *first* consists, according to Mr. Tomes,* of a very delicate areolar tissue composed of delicate fibres and bands, whose meshes are occupied with a thick clear homogeneous fluid or plasma, scattered through which are a number of nucleated cells; the whole being enclosed in a dense, structureless, pellucid membrane. The papilla is copiously supplied with blood-vessels, which originate in a trunk that enters its base (Fig. 59), and then ramify and spread through its whole substance, at last forming a capillary network which terminates in loops near its apex. These vessels are accompanied by nerves, which also have looped terminations.—The changes in which the conversion of the papilla into the tooth-substance consists, commence near the coronal surface; where the cells of the pulp, lying beneath its investing membrane, are found to have undergone enlargement, and to be thickly scattered at pretty regular intervals through a sub-granular uniting medium, the intermediate areolar tissue having now disappeared (Fig. 60, A); the cavities of the cells are occupied by granular matter. The blood-vessels now begin to retreat from the coronal surface of the papilla, so that few are seen in the part which exhibits this *second* stage of development.—At a later period, the cells of the pulp exhibit a regular linear arrangement (B), their extremities coming into close approximation with each other; and the

Fig. 59.

Vessels of *Dental Papilla.*

Fig. 60.

A B C

Sections of the *Dentinal Pulp* in successive stages of its development.

termediate connecting substance acquires a much firmer character. ach cell, after falling into line, undergoes transverse fission, and each

* "Lectures on Dental Physiology and Surgery," p. 84.

T 2

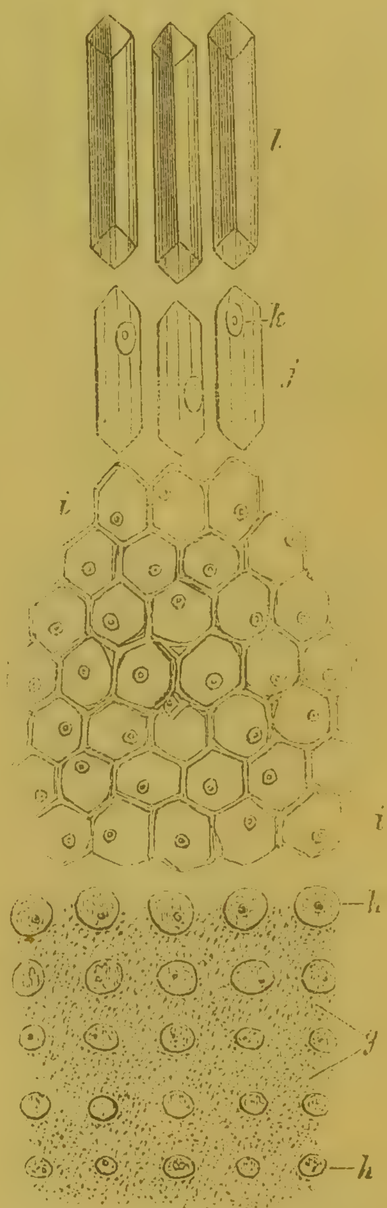
division elongates; so that in this manner their extremities are brought into close apposition. Whilst this is taking place, their cavities also increase in length, and extend to the extremities of the cells; and at last the intervening septa disappear, so that the cell-cavities become continuous, and constitute tubes (c). At the same time, the calcifying process is taking place in the intercellular substance, and in the thick walls of the cells; and thus the dentine with its tubuli are generated. This process progressively extends itself from the surface of the pulp, towards its centre; for as the more external and larger cells become hardened, the inner ones increase in size, assume the linear arrangement, and in their turn become converted into dentine; until at last the great bulk of the pulp is transformed, leaving only a comparatively small portion, which, with the nerves and blood-vessels, occupies the central cavity of the tooth. In this progressive development, it often happens that *two* of the more external cells unite with *one* of the cells next to them on the internal side (Fig. 60, c), their two canals also uniting to form one; and by the frequent repetition of this process of union it happens, that the number of dentinal tubes gradually diminishes as we pass from the periphery towards the centre.—The 'nodular layer' (Fig. 56) which commonly exists near the surface of the tooth-fang, and the similar structure which occasionally (though abnormally) presents itself elsewhere, are considered by Mr. Tomes to depend upon the partial continuance of the original areolar structure of the pulp, whilst it is undergoing calcification; the calcifying process having either commenced at an unusually early period, when as yet the linear arrangement of the cells for the development of the tubular structure has not yet taken place, so that the dentinal substance thus formed has a very imperfect character; or, in other cases, the space originally occupied by the areolar texture not having been filled up, whilst the cells were undergoing development into tubes, so that vacuities are left, which preserve its original form.*

280. The Enamel-pulp is not formed until after the dental papilla has become enclosed in a capsule, by the process to be presently described; and it is derived from the free inner surface of the capsule, of which its cells may be considered as the epithelium. Of this pulp, however, which fills the whole space between the surface of the papilla and the lining of the follicle, only that portion which is immediately adjacent to the former is the actual matrix of the enamel; the remainder serves but a temporary purpose, and afterwards disappears. In its earliest condition, the enamel-pulp, according to Mr. Tomes, bears a strong resemblance to the first stage of the dentinal; for it consists of a meshwork of very fine fibres (which seem to be composed of the yellow element), whose interspaces are occupied by a thick transparent fluid, floating in which are some peculiar nucleated cells; the fluid, however, is more abundant, and the cells are fewer, than in the dentinal pulp. In the stratum of the pulp nearest to the surface of the dentinal papilla, the cells multiply, and are developed into the form of a prismatic epithelium (Fig. 61, *j*); but above

* In the above sketch of the history of the development of the Dentinal pulp, the account given by Mr. Tomes has been followed, as that which the Author's own observations lead him to prefer to the account given in former editions on the authority of Prof. Owen.—See also the "Beiträge sur mikroskopischen Anatomie der menschlichen Zähne," of Dr. J. Czermák.

this, the cells assume the stellate form, and their radiating prolongations coalesce, so that a very curious tissue is formed which, though not uncommon in Plants (as, for instance, in the Rush) is very unusual in animals.* In the early stage of its development, the enamel-pulp is traversed throughout by blood-vessels, which are prolonged into it from the inner lining of the capsule; but these gradually retreat, and when the calcification of the enamel-matrix is going on, they have entirely withdrawn themselves from the pulp, the membranous lining of the capsule, however, being itself highly vascular and somewhat villous. One purpose of the stellate tissue would seem to be, to afford a space for the columnar tissue and the dentinal pulp to extend themselves into without resistance, and to serve as a protection to these structures during their growth; but it may also select from the nutrient materials supplied by the blood, those which the cells of the enamel-matrix require, and may prepare it for being finally appropriated by them. These cells gradually fill themselves with calcareous salts, which would seem to be deposited in them in a purely crystalline condition, and not to be conjoined (as in Bone and Dentine) with organic matter; for the small proportion of the latter, which chemical analysis shows to exist in Enamel (§ 278), is probably employed wholly in forming the walls of the prismatic cells, which themselves become penetrated by the consolidating substance. That so large a proportion of the calcifying material of Enamel consists of the *phosphate* of lime, is evidently the cause of its extraordinary hardness (§ 76). The calcification begins on the surface of the dentinal papilla, which is excavated into shallow cups that receive the ends of the enamel-columns; and these columnar cells are at first so short, as to constitute but a very thin layer. As calcification takes place at their bases, however, their apices lengthen; and this either

Fig. 61.



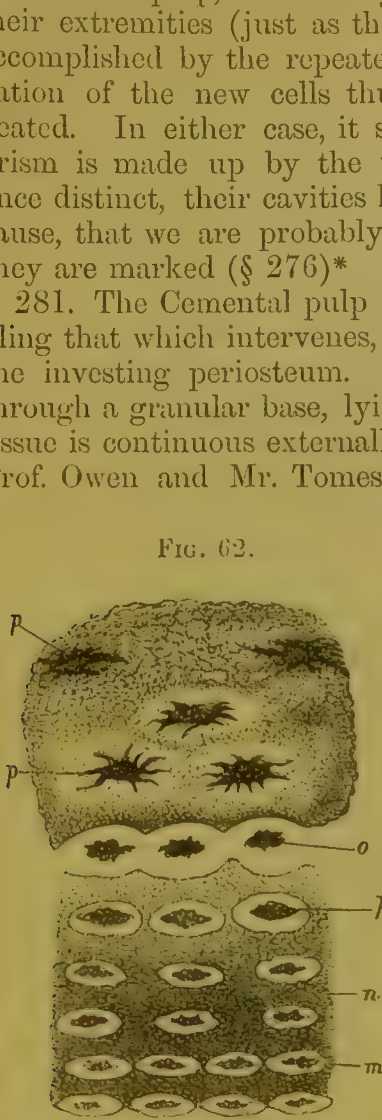

Formation of *Enamel*:—*h*, primary cells suspended in fluid blastema *g*; *i*, the same more fully developed and become angular; *j*, the same becoming prismatic; *k*, the nucleus disappearing; *l*, the modified prismatic cells, filled with calcareous salts, forming the fibres of enamel.

* This curious tissue was first described by Messrs. Todd and Bowman, in their "Physiological Anatomy," vol. ii. p. 175; these authors, however, do not speak of it as composed of stellate cells, but describe it as consisting of a mesh of short fibres, meeting in numberless points, at each of which a transparent clear nucleus is visible. The Author agrees with Mr. Tomes in the interpretation he has given to it; more especially since, as Mr. Tomes remarks, the large floating cells of parts of the pulp in which this tissue does not yet exist, present indications of an approach towards the stellate form.

by the formation, addition, and coalescence, of new cells furnished by the enamel-pulp, or else by the subdivision of the prismatic cells at their extremities (just as the increase in length of a Conferva is usually accomplished by the repeated fission of the terminal cell), and the elongation of the new cells thus formed, the process being continually repeated. In either case, it seems that the entire length of each enamel-prism is made up by the union of a linear series of cells which were once distinct, their cavities having become continuous; and it is to this cause, that we are probably to attribute the transverse striæ with which they are marked (§ 276)*

281. The Cemental pulp seems to be a substance very closely resembling that which intervenes, in the growing bone, between its surface and the investing periosteum. It is composed of nucleated cells, scattered through a granular base, lying in the areolæ of a fibrous tissue; and this tissue is continuous externally with that of the dental sac. According to Prof. Owen and Mr. Tomes, the process of calcification, which begins in the part nearest the dentine, consists in the absorption of calcareous matter into the cavities of the cells, in the more close aggregation of the cells with each other, and in the changes which take place coincidently in their nuclei. These, which are at first large granular spots of a rounded form, send out radiating prolongations, which extend quite to the borders of the cell; and as the calcareous salts which penetrate the cell, are not deposited in the space occupied by the nuclei, the stellate cavities, or lacunæ and diverging canaliculi, are left, which are so analogous to those of bone, as to serve to identify the two tissues. In the Cementum, as in Bone and Dentine, the consolidating substance appears to consist of mineral and organic matter in a state of chemical union. The boundaries of the original cells disappear; so that nothing remains in the fully-formed cementum, to mark its cellular origin, save the stellate lacunæ which represent the positions of the formerly-existing nuclei. The thin layer of cementum, which is affirmed by Mr. Nasmyth to cover the crown of the newly-formed tooth, would seem to be formed by the calcification of the tooth-capsule itself.†

Fig. 62.



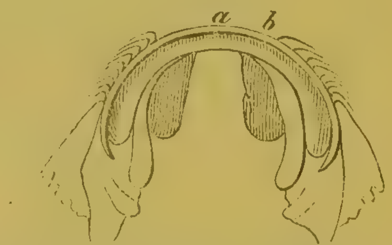

Formation of the *Cementum*:—*m*, primary cells; *p*, their granular nuclei; *n*, more minutely granular blastema; *o*, the primary cell enlarged, and receiving the hardening salts; *n'*, calcified blastema; *p*, *p'*, stellate nuclei of fully-formed cemental cells.

* A precisely similar set of appearances has been described by the Author in the prismatic cellular structure forming the shells of certain Mollusks, and has been shown by him to be probably due to the same cause,—the coalescence of flattened epithelial cells in vertical piles. (See the "Reports of the British Association," 1844, 1847.

† For an account of Prof. Owen's researches on the comparative structure and development of the Teeth in the lower Vertebrata, see his "Odontography," and his Art. *Teeth* in the 'Cyclop. of Anat. and Physiol.," also "Princ. of Phys., Gen. and Comp.," §§ 212–219, 322 *f*, *g*, 324 *o*, *p*, and 326 *o*, *p*, *q*.

282. Having thus considered the mode of development of the several components of the Human Teeth, we are prepared to inquire into the history of evolution of each tooth as a whole, and into the successional relations of the different teeth to each other. This topic has been especially elucidated by Prof. Goodsir,* whose account will be here followed. —At the 6th week of Fœtal life, a deep narrow groove may be perceived, in the upper jaw of the Human embryo, between the lip and the rudimentary palate; this is speedily divided into two by a ridge, which afterwards becomes the external alveolar process; and it is in the inner groove, that the germs of the teeth subsequently appear. Hence this may be termed the *primitive dental groove* (Fig. 63). At about the 7th week, an ovoidal papilla, consisting of a granular substance, makes its appearance on the floor of the groove, near its posterior termination; this papilla is the germ of the anterior superior 'milk' Molar tooth. About the 8th week, a similar papilla, which is the germ of the Canine tooth, arises in front of this; and during the 9th week, the germs of the Incisors make their appearance under the same form. During the 10th week, processes from the sides of the dental groove, particularly the external one, approach each other, and finally meet before and behind the papilla of the anterior Molar; so as to inclose it in a follicle, through the mouth of which it may be seen. By a similar process, the other teeth are gradually inclosed in corresponding follicles. The germ of the posterior 'milk' Molar also appears during the 10th week, as a small papilla. By the 13th week, the follicle of the posterior Molar is completed; and the several papillæ undergo a gradual change of form. Instead of remaining, as hitherto, simple, rounded, blunt masses of granular matter, each of them assumes a particular shape; the Incisors acquire in some degree the flattened form of the future teeth; the Canines become simple cones; and the Molars become cones flattened transversely, somewhat similar to carnivorous molars. During this period, the papillæ grow faster than the follicles; so that the former protrude from the mouth of the latter. At this time, the mouths of the follicles undergo a change, consisting in the development of their edges, so as to form *opercula;* which correspond in some measure with the shape of the crowns of the future teeth. There are two of these opercula in the Incisive follicles, three for the Canines, and four or five for the Molars. At the 14th week, the inner lip of the dental groove has increased so much, as to meet and apply itself in a valvular manner to the outer lip or ridge, which has been also increasing. The follicles at this time grow faster than the papillæ, so that the latter recede into the former. The primitive dental groove then contains ten papillæ, inclosed in as many follicles; and thus all necessary provision is made for the production of the first set of teeth. (This series of changes is represented in Fig. 64, *a—g.*) The groove is now situated, however, on a higher level than at first; and it has undergone such a change by the closure of its

FIG. 63.



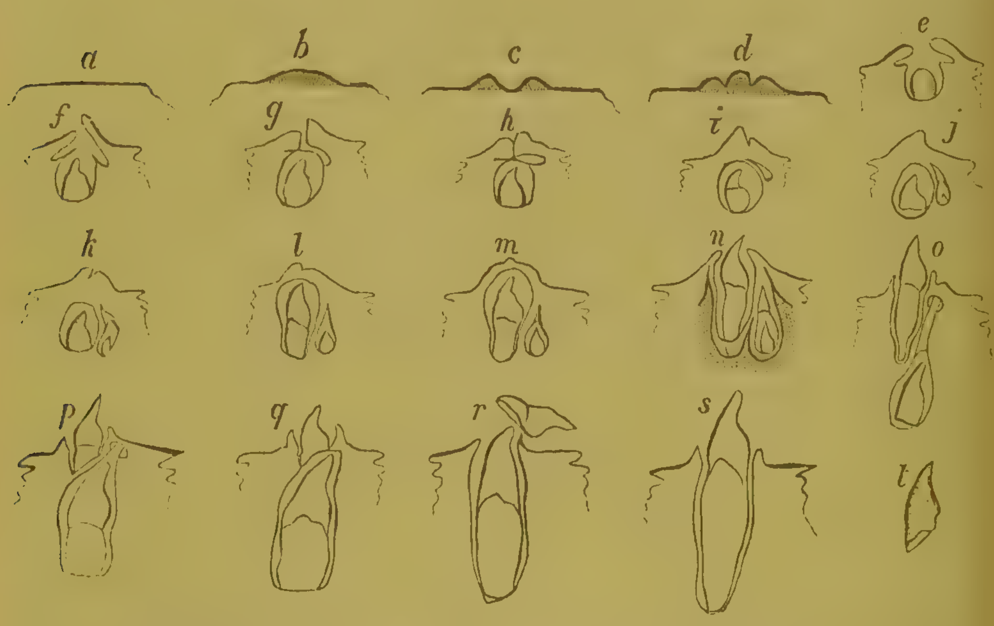

Upper jaw of Human Embryo at sixth week; showing *b*, the *Primitive Dental Groove*, behind *a*, the Lip.

* "Edinburgh Medical and Surgical Journal," vol. li.

edges, as to entitle it to the distinctive appellation of *secondary dental groove*. It is in this secondary groove that those structures originate, which are destined for the development of the second or 'permanent' set of Teeth,—of those at least which replace the 'milk' Teeth. This is accomplished in the following manner.

283. At about the 14th or 15th week, a little crescentic depression may be observed, immediately behind the inner opercula of each of the 'milk' tooth-follicles. This depression gradually becomes deeper, and constitutes what may be termed a *cavity of reserve;* adapted to furnish delicate mucous membrane, for the future formation of the sacs and pulps of the ten anterior 'permanent' teeth. These 'cavities of reserve' are gradually separated from the 'secondary dental groove,' by the adhesion of their edges; and they thus become minute compressed sacs, situated between

Fig. 64.




**Diagrams illustrative of the formation of a *Temporary*, and its corresponding *Permanent Tooth*, from a Mucous Membrane.**

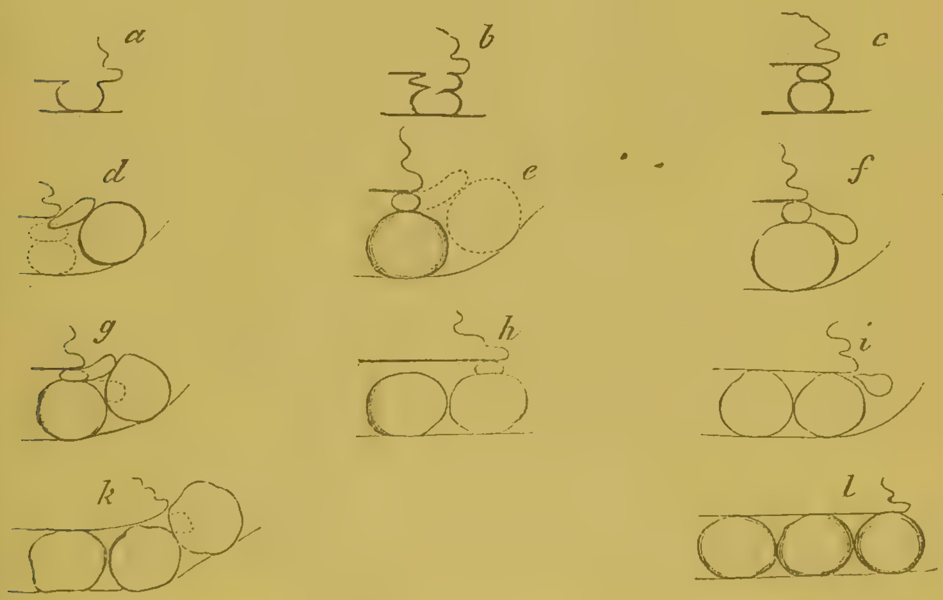
the surface of the gum and the milk-sacs. They gradually recede, however, from the surface of the gum, so as to be posterior instead of interior to the milk-sacs; and at last they imbed themselves in the submucous cellular tissue, which has all along constituted the external layer of the milk-sac. The implantation of the 'permanent' tooth-sacs in the walls of the temporary follicles, gives to the former the appearance of being produced by a gemmiparous process from the latter.—This series of changes is represented in Fig. 64, *g*—*n*.

284. We now turn to the 'milk' teeth, the papillæ of which, from the time that their follicles close, become gradually moulded into their peculiarly Human shape. The Molar pulps begin to be perforated by three canals, which, proceeding from the surface towards the centre, gradually divide their primary bases into three secondary bases; and these become developed into the fangs of the future teeth. Whilst this is going on, the sacs grow more rapidly than the papillæ, so that there is an intervening

space, which is filled with a gelatinous granular substance—the enamel-pulp; this closely applies itself to the surface of the papilla, but does not adhere to it. At this period, the tubercles and apices of the papillæ or pulps become converted into *dentine* or tooth-substance, in the manner already stated (§ 279); and the granular matter is absorbed as fast as this appears; so that, when the process of conversion has reached the base of the pulp, the interior of the dental sac is left in the villous and vascular condition of a true Mucous membrane, having upon it a very thin layer of the prismatic epithelium which constitutes the true enamel-matrix (§ 280). The opercula, which close the mouth of the dental sac, attain a much greater development in the Molar teeth of Herbivorous animals; where they dip down into the midst of the dentinal pulp, and give origin to insulated spots both of enamel and cementum. It has been remarked by Mr. Lintott, that the lines along which the opercula meet, on the crown of the Human molar teeth,—that is to say, the groove which separates their tubercles,—is by far the most frequent seat of incipient decay; probably from its tissue having been at the first less perfectly formed than that of the remainder.

285. Whilst these changes are going on, other important preparations are being made for the 'permanent' set. The general adhesion of the edges of the 'primitive dental groove' (§ 282), does not invade the portion, which is situated behind the posterior 'milk' follicle; this retains its original appearance for a fortnight or three weeks longer, and affords a

FIG. 65.




Diagrams illustrative of the formation of the three *Permanent Molar Teeth*, from the non-adherent portion of the Dental Groove.

nidus for the development of the papilla and follicle of the anterior 'permanent' Molar tooth, which is developed in all respects on the same plan with the 'milk' teeth. After its follicle has closed, the edges of the dental groove meet over its mouth; but as the walls of the groove do not adhere, a considerable cavity is left between the sac of the tooth and the surface of the gum. The cavity is a 'reserve' of delicate mucous membrane, to afford materials for the formation of the second 'permanent'

Molar, and of the third 'permanent' Molar, or 'wisdom-tooth.' (The process just described is represented in Fig. 65, *a*—*c*.) It will be convenient here to continue the account of the development of these teeth, although it takes place at a much later period. Towards the end of fœtal life, the increase of the bulk of the 'milk' tooth-sacs takes place so much more rapidly than the growth of the jaw, that the sac of the anterior 'permanent' Molar is forced backwards and upwards, into the maxillary tuberosity; and thus it not only draws the surface of the gum in the same direction, but lengthens-out the great 'cavity of reserve' (Fig. 65, *d*). During the few months which succeed birth, however, the jaw is greatly lengthened; and when the infant is eight or nine months old, the anterior 'permanent' Molar resumes its former position in the posterior part of the dental arch; and the great 'cavity of reserve' returns to its original size and situation (*e*). This cavity, however, soon begins to bulge out at its posterior side, and projects itself, as a sac, into the maxillary tuberosity (*f*); a papilla or pulp appears in its fundus; and a process of contraction separates this portion of it from the remainder. Thus the formation of the second 'permanent' Molar from the first, takes place on precisely the same plan with the formation of the 'permanent' Bicuspids from the temporary Molars. The new sac at first occupies the maxillary tuberosity (*g*); but the lengthening of the jaw gradually allows it to fall downwards and forwards, into the same line, and on a level with the rest (*h*). Before it leaves the tuberosity altogether, the posterior extremity of the remainder of the 'cavity of reserve' sends backwards and upwards its last offset—the sac and pulp of the 'wisdom-tooth' (*i*); this speedily occupies the tuberosity, after the second molar has left it (*j*); and ultimately, when the jaw lengthens for the last time, at the age of nineteen or twenty, it takes its place at the posterior extremity of the range of the adult teeth (*k*). Thus, the 'wisdom-teeth' are the second products of the posterior or great 'cavities of reserve;' and the final effects of development in the 'secondary dental groove.'

286. We have thus sketched the history of the Development of the Teeth, up to the time when they prepare to make their way through the gum. The first stage of this development may be termed the *papillary;* and the second the *follicular*. The latter terminates, when the papillæ are completely hidden by the closure of the mouths of the follicles, and of the groove itself. The succeeding stage, which has long been known as the *saccular*, is the one during which the whole formation of the Dentine, and of the Enamel, takes place. It is during this period, also, that the ossification of the jaw is being effected; and that the bony sockets are formed for the teeth, by the consolidation of the anterior and posterior ridges bounding the alveolar groove (in which the dental groove was originally imbedded), and of the interfollicular septa, which are produced by the meeting of transverse projections from these ridges.—We have now only to consider the fourth or *eruptive* stage; that in which the Teeth make their way through the gum. This process chiefly results from the lengthening of the fang, by the addition of new dentinal substance; so that the crown of the tooth is made to press against the closed mouth of the sac (Fig. 64, *m*). This at last gives way, and the sac then assumes its previous condition of an open follicle. When the edge of the tooth has once made its way through the gum, it advances more rapidly than

can well be accounted for by the usual rate of lengthening of its fang; and this appears to be due to the separation of the bottom of the sac from the fundus of the alveolus; so that the whole tooth-apparatus is carried nearer to the surface, leaving a space at the bottom of the alveolar cavity, in which the further lengthening of the root can take place (*n*). The open portion of the sac remains as the narrow portion of the gum, which forms a vascular border and groove round the neck of the perfected tooth (*o*). The deeper portion of the sac adheres to the fang of the tooth; and it is here that the cemental pulp is found, constituting (as it were) its inner layer. What is commonly denominated the periosteum of the Tooth, really belongs as much to the Alveolus. It is connected with the tooth by the submucous cellular tissue, which originally intervened between the tooth-sac and the walls of the osseous cavity.—During the period that the 'milk' teeth have been advancing, along with their sockets, to their perfect state and ultimate position, the 'permanent' sacs have been receding in an opposite direction, and have with their bony crypts been enlarging; and at last they occupy a position almost exactly below the former (*n* and *o*). They still retain a communication with the gum, however; the channel by which they descended not having completely closed up, and the neck of the sac being elongated into a cord which passes through this. The channels may afterwards serve as the *itinera dentium*, and the cords as *gubernacula;* but it is uncertain whether they really afford any assistance in directing the future rise of the tooth to the surface; the successive stages of which are represented in Fig. 64, *p*—*t*. The sacs of the permanent teeth derive their first vessels from the gums; ultimately they receive their proper dental vessels from the milk-sacs; and, as they separate from the latter into their own alveoli, the newly-formed vessels, conjoining into common trunks, also retire into permanent dental canals, and gradually become the most direct channels for the blood transmitted through the jaw.—The history of development in the Lower Jaw is very nearly the same; the chief difference being in the origin and situation of the primitive dental groove.

287. The following interesting generalizations respecting the development of the teeth, result from Prof. Goodsir's researches.—1. The 'milk' teeth are formed on both sides of either jaw in three divisions, a Molar, a Canine, and an Incisive; in each of which, dentition proceeds in an independent manner. 2. The dentition of the whole arch proceeds from behind forwards; the Molar division commencing before the Canine, and the Canine before the Incisive. 3. The dentition of each of the divisions proceeds in a contrary direction, the anterior Molar appearing before the posterior, the central Incisor before the lateral. 4. Two of the subordinate phenomena of nutrition also follow this inverse law;—the follicles closing by commencing at the median line and proceeding backwards; and the dental groove disappearing in the same direction. 5. Dentition commences in the upper jaw, and continues in advance during the most important period of its progress. The development of the superior Incisors, however, is retarded by a peculiar cause; so that the inferior Incisors have the priority in the time of their completion and appearance. 6. The germs of the 'permanent' teeth, with the exception of that of the anterior Molar, appear in a direction from the median line backwards. 7. The 'milk' teeth originate, or are developed, from mucous membrane. 8. The

'permanent' teeth, also originating from mucous membrane, are of independent origin, and have no connection with the 'milk' teeth. 9. A Tooth-pulp and its sac must be referred to the same class of organs, as the combined papilla and follicle from which a Hair or Feather is developed.

288. The following is the usual order, and period of appearance, of the several pairs of 'milk' teeth. The four central Incisors first present themselves, usually about the 7th month after birth, but frequently much earlier or later: those of the lower jaw appear first. The lateral Incisors next show themselves, those of the lower jaw coming through before those of the upper; they usually make their appearance between the 7th and 10th months. After a short interval, the anterior Molars present themselves, generally soon after the termination of the 12th month; and these are followed by the Canines, which usually protrude themselves between the 14th and 20th months. The posterior Molars are the last, and the most uncertain in regard to their time of appearance; this varying from the 18th to the 36th month. In regard to all except the front teeth, there is no settled rule as to the priority of appearance of those in the upper or under jaw; sometimes one precedes, and sometimes the other; but in general it may be stated, that, whenever one makes its appearance, the other cannot be far off. The same holds good in regard to the two sides, in which development does not always proceed exactly *pari passu*.—The period of Dentition is sometimes one of considerable risk to the Infant's life; and this especially when an irritable state of the nervous system has been brought about by unsuitable food, unwholesome air, or some other cause of disordered health. In such cases, the pressure upon the nerves of the gum, which necessarily precedes the opening of the sac and the eruption of the tooth, is a fruitful source of irritation; producing disturbance of the whole system, and not unfrequently giving origin to fatal Convulsive affections. These last have been particularly studied by Dr. M. Hall, who recommends the free use of the gum-lancet, as a most important means of prevention and cure; but the Author has no doubt that too much attention has been given to the immediate source of the irritation, and too little to the general state of the system; and that constitutional treatment, especially change of air and improvement of the diet, is of fundamental importance. In infants whose general health is good, and who are not over-fed, Dentition is a source of but very trifling general disturbance; a slight febrile action, lasting but for a day or two, being all that marks the passage of the tooth through the capsule; and its eruption through the gum taking place without the least indication of suffering or disorder. Any existing malady or abnormal tendency, however, is pretty sure to be aggravated during the 'cutting of the teeth;' and it is, therefore, of the greatest consequence that the infant should be withdrawn, during this period, from all injurious influences; and that no irregularity of diet, or deficiency of fresh air and exercise, should operate to its disadvantage.

289. After the lapse of a few years, the further elongation of the jaw permits the appearance of the first true Molar; which, as already remarked, is really a 'milk' tooth, so far as its formation is concerned. This commonly presents itself about the middle or end of the 7th year; sometimes preceding, and sometimes following, the exchange of the central Incisors, which takes place about the same time. When the 'permanent'

teeth have so much enlarged, that they can no longer be contained within their own alveoli, they press upon the anterior parietes of those cavities, and cause their absorption; so that each tooth is allowed to come forwards, in some degree, into the lower part of the socket of the corresponding 'temporary' tooth. The root of the temporary tooth now begins to be absorbed, generally at the part nearest its successor; and this absorption proceeds as the new tooth advances, until the root of the 'milk' tooth is completely removed; when its crown falls off, leaving room for the permanent tooth to supply its place (Fig. 64, *p*—*t*). This absorption is usually regarded as due to the pressure of the permanent tooth, but such does not appear to be the case; for it is mentioned by Mr. Bell, that it is not an uncommon occurrence for the root of the temporary tooth to be wholly absorbed, and for the crown to fall out spontaneously, long before the succeeding tooth has approached the vacant space. The same has been remarked by Mr. Bell, of the cavity in the jaw which is formed for the reception of the sac of the 'permanent' tooth, at the time that it buds off from that of the 'milk' tooth; the excavation being often seen to commence before the new sac is formed. Hence, although the two processes, growth and absorption, are usually contemporaneous in each instance, they are by no means dependent on each other. Still it would seem that the existence, if not the pressure, of the new tooth is necessary to determine the absorption of the old; for cases are not unfrequent, in which the temporary teeth retain their situation in the mouth, with considerable firmness, until adult age,—the corresponding permanent ones not having been formed.

290. In the successive replacement of the 'milk' teeth by the 'permanent' set, a very regular order is usually followed. The middle Incisors are first shed and renewed, and then the lateral Incisors. The anterior 'milk' Molars next follow; and these are replaced by the anterior Bicuspid teeth. About a year afterwards, the posterior 'milk' Molars are shed, and are replaced in like manner by Bicuspid teeth. The Canines are the last of the 'milk' teeth to be exchanged; the development of the new ones not taking place until the 12th year. In the succeeding year, the second pair of the true Molars appears; the third pair, or *dentes sapientiæ*, are seldom developed until three or four years subsequently, and often much later.—It has been proposed * (and, from the evidence adduced in its favour, the proposition would seem entitled to considerable attention) to adopt the successive stages in the Second Dentition, as standards for estimating the physical capabilities of Children, especially in regard to those two periods which the Factory Laws render it of the greatest importance to determine, namely, the ages of *nine* and *thirteen* years. Previously to the former, a Child is not permitted to work at all; and up to the latter, it may be only employed during nine hours a day. The necessities or the cupidity of Parents are continually inducing them to misrepresent the ages of their children; and it has been found desirable, therefore, to seek for some test, by which the capability of the Child may be determined, without a knowledge of its age. A standard of Height has been adopted by the Legislature for this purpose; but upon grounds

* "The Teeth a Test of Age, considered with reference to the Factory Children." By Edwin Saunders.

which, physiologically considered, are very erroneous; since, as is well known, the tallest children are frequently the weakliest. According to Mr. Saunders, the degree of advance of the Second Dentition may be regarded as a much more correct standard of the degree of general development of the organic frame, and of its physical powers; and it appears from his inquiries, that it may be relied-on as a guide to the real age, in a large proportion of cases; whilst no serious or injurious mistake can ever arise from its use. It may happen that local or constitutional causes may have slightly retarded the development of the Teeth; in which case the age of the individual would rather be under-estimated, and no harm could ensue: on the other hand, instances of premature development of the Teeth very rarely, if ever, occur: so that there is no danger of imputing to a Child a capability for exertion which he does not possess, as the test of height is continually doing. Moreover, if such an advance in Dentition should occur, it might probably be regarded as indicative of a corresponding advance in the development of the whole organism; so that the real capability would be such as the teeth represent it.

291. The following is Mr. Saunders's statement of the Ages, at which the 'permanent' Teeth respectively appear. The first true Molars usually make their appearance towards the end of the 7th year. Occasionally one of them protrudes from the gum at 6, or more frequently at $6\frac{1}{2}$ years of age; but the evolution of the whole of them may be regarded as an almost infallible sign of the Child's being 7 years old. In other instances, where the tooth on one side of the mouth is freely developed, it is fair to reckon the two as having emerged from their capsule; since the development of the other must be considered as retarded. This rule only holds good, however, in regard to teeth in the same row; for the development of the teeth in either jaw must not be inferred, from that of the corresponding teeth in the other. With this understanding, the results of the application of the following table will probably be very near the truth.

| | |
|---|---|
| Central Incisors developed at . . . | 8 years. |
| Lateral Incisors . . . . | 9 „ |
| First Bicuspid . . . . . | 10 „ |
| Second Bicuspid . . . . | 11 „ |
| Canines . . . . . . | 12 to $12\frac{1}{2}$ |
| Second Molars . . . . | $12\frac{1}{2}$ to 14 |

The following are the results of the application of this test, in a large number of cases examined by Mr. Saunders. Of 708 Children of *nine* years old, 530 would have been pronounced by it to be near the completion of their *ninth* year; having the central, and either three or four lateral, incisors fully developed. Out of the remaining 178, it would have indicated that 126 were $8\frac{1}{2}$ years old, as they presented one or two of the lateral Incisors; and the 52 others would have been pronounced 8 years old, all having three or four of the central Incisors. So that the extreme deviation is only 12 months; and this in the inconsiderable proportion (when compared with the results obtained by other means) of 52 in 708, or $7\frac{1}{3}$ per cent. Again, out of 338 children of 13 years of age, 294 might have been pronounced with confidence to be of that age, having the Canines, Bicuspid, and second Molars, either entirely developed, or with only the deficiency of one or two of either class. Of the 44 others, 36 would have been considered as in their 13th year, having one of the

posterior Molars developed; and 8 as near the completion of the 12th, having two of the Canines, and one or two of the second Bicuspid. In all these instances, the error is on the favourable side,—that is, on the side on which it is calculated to prevent injury to the objects of the inquiry; in no instance did this test cause a Child to be estimated as older or more fit for labour than it really was.*

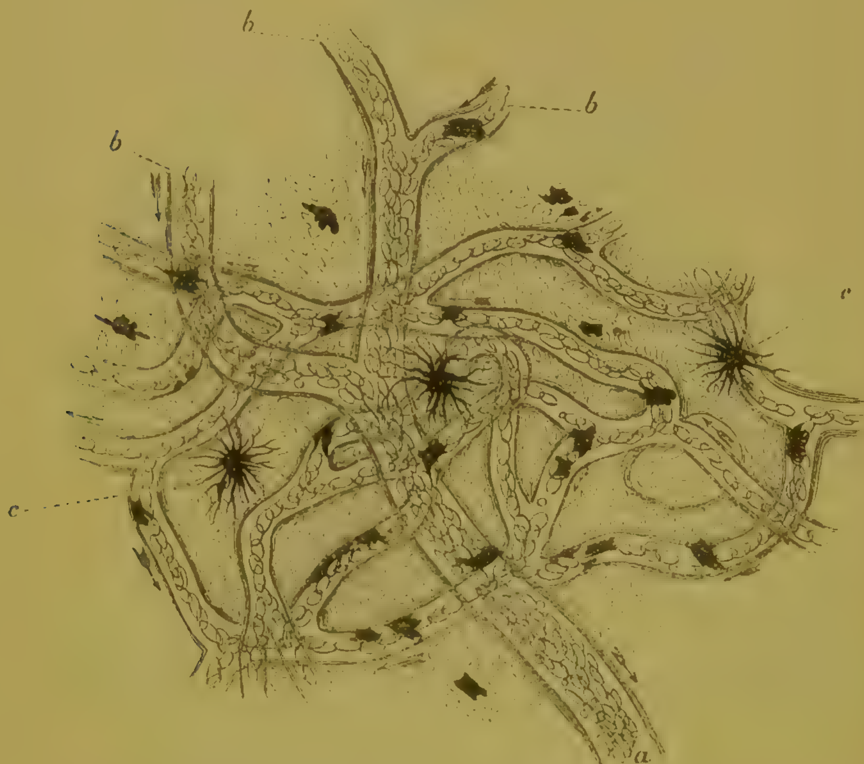
### 5. *Of the Simple Tubular Tissues;—Capillary Blood-vessels and Absorbents.*

292. We have seen that all the Animal Tissues, whose structure has been yet considered, derive the materials of their growth and renovation from the nutrient fluid; which is brought into a more or less close relation with their elementary parts, by means of *Capillary Blood-vessels.* These seem to have a claim to be regarded as among the elementary parts of the fabric; since they are formed quite independently of the larger trunks, and have little in common with them in their function. All those changes which take place between the blood and the surrounding parts, whether ministering to the operations of Nutrition, Secretion, or Respiration, occur during its movement through them; and the function of the larger trunks is merely to bring to them a constant supply of fresh blood, regulated according to the demand created by the actions to which it is subservient, and to remove the fluid which has circulated through them. In Man, as in all the higher Animals,—in the adult condition at least,—the Capillary circulation is entirely carried on through tubes having distinct membranous parietes. These tubes commonly form a minutely-anastomosing network; into which the blood is brought by the ramifications of the arteries on one side, and from which it is returned by the radicles of the veins on the other. The walls of the tubes are composed of a delicate membrane, in which an appearance of transverse striation (as if produced by minute annular fibres) can sometimes be discerned. The diameter of the Capillaries varies in different animals, in accordance with that of their blood-corpuscles; thus the Capillaries of the Frog are, of course, much larger than those of Man. The diameter of the latter appears, from the measurements of Weber, Müller, and others, to vary from about the 1-3700th to the 1-2500th of an inch; but as they can only be examined after death, it is probable that these statements are not altogether exact, particularly as tubes of the smallest of the above sizes would not admit ordinary blood-corpuscles. The dimensions of the indi-

* The value of this test, as compared with that of Height, is manifested by a striking example adduced by Mr. Saunders. The height of one lad, J. J., aged 8 years and 4 months, was 4 feet and ¾ of an inch; that of another boy, aged 8 years and 7 months, was only 3 feet 7½ inches. According to the standard of height adopted by the Factory Commissioners (namely 3 feet 10 inches), the *taller* lad would have been judged fit for labour, whilst the *shorter* would have been rejected. The Dentition of the latter, however, was further advanced than that of the former; for he had two of the lateral Incisors, whilst the former had only the central: and the determination of their relative physical powers, which would have been thus formed, would have been in complete accordance with the truth. The elder boy, though shorter than the other by 5½ inches, possessed a much greater degree both of corporeal and mental energy, and his pulse was strong and regular; whilst that of the younger lad, who was evidently growing too fast, was small and frequent.—An instance even more striking has come under the Author's own observation.

vidual vessels, indeed, are by no means constant; as may be seen by watching the Circulation in any transparent part, for some little time. Putting aside the general changes in diameter, which result from circumstances affecting all the capillaries of a part, it may be observed that a single capillary will sometimes enlarge or contract by itself, without any obvious cause. Thus, the stream of blood will sometimes be seen to run into passages, which were not before perceived; and it has hence been

Fig. 66.




Capillary plexus in a portion of the web of a *Frog's* foot, magnified 110 diameters:—*a*, trunk of vein; *b*, *b*, its branches, *c*, *c*, pigment-cells.

supposed that they were new excavations, formed by the retreating or removal of the solid tissue through which it passes. But a more attentive examination shows, that such passages are real capillaries, which did not, at the time of the first observation, admit the stream of blood-corpuscles, in consequence of the contraction of their calibre, or of some other local impediment; and that they are brought into view by the simple increase in their diameter. The compression of one of the small arteries will generally occasion an oscillation of the corpuscles of blood in the smallest capillaries, which will be followed by the disappearance of some of them; but when the obstruction is removed, the blood soon regains its previous velocity and force, and flows into exactly the same passages as before.

293. The opinion was long entertained, that there are vessels adapted to supply the white or colourless tissues; carrying from the arteries the 'liquor sanguinis,' and leaving the corpuscles behind, through inability to receive them. But such a supposition is altogether groundless. Some of the white tissues, as Cartilage, are altogether destitute of vessels; and in others, the supply of blood is so scanty, as not to communicate to them

any decided hue. It is evident from what has been already stated, that the idea that Nutrition can *only* be carried on by means of Capillary vessels, is entirely gratuitous. There is no essential difference, in fact, between the nutrition of the non-vascular tissues, and that of the islets in the midst of the network of capillary vessels which traverses the most vascular. In both cases, the nutrient materials conveyed by the blood are absorbed by the cells or other elementary parts of the tissue immediately adjoining the vessels, and are imparted by them to others which are further removed; and the only difference lies in the amount of the portion of tissue which has to be thus traversed. There is great variety in this respect, as we have seen, among the vascular tissues; and we are only required to extend our ideas, from the largest of the islets which we find in these, to the still more isolated structures of which the non-vascular tissues are composed. The distribution of Capillaries through the vascular tissues, and the character of the reticulation which they form, vary so greatly in the different parts of the fabric, that it is possible to state with tolerable certainty the nature of the part, from which any specimen has been detached,—whether a portion of skin, mucous membrane, serous membrane, muscle, nerve, fat, areolar tissue, gland, &c. But the arrangement of vessels peculiar to each, evidently has reference only to the convenience of the distribution of blood among the elementary parts of the tissue, and varies with their form. It is not possible to imagine that it has any other relation than this to their function; since, as already shown, the function of each separate element of the organ, of which that of the entire organ is the aggregate, is due to its own inherent vital powers,—the supply of blood being only required as furnishing the material on which these are to be exercised.

294. It has been rendered highly probable, by the observations of Schwann and other Histologists, that the Capillaries of Animals originate in cells, like the straight and anastomosing Ducts of Plants. Bodies having the appearance of cell-nuclei may frequently be seen in the walls of the capillaries of embryos and of tadpoles; and these are too wide apart to warrant the idea, that they are the nuclei of epithelial cells, such as those which line the larger vessels. Similar nuclei may be brought into view in the capillaries of adult animals, by treating them with acetic acid; and they are particularly well seen in the Pia Mater, which consists almost entirely of a congeries of blood-vessels (Fig. 67). The accompanying figure shows the contrast between the long oval nuclei *b*, *b*, imbedded at intervals in the walls of the true capillaries, and rather projecting on their exterior; and the nuclei of the epithelium-cells, *f*, *f*, lining the interior of a larger branch, which last are more numerous and of less regular form, and are sometimes placed transversely to the direction of the tube.—The first formation of the Capillary blood-vessels in the vascular area in the Bird's egg, seems to be effected entirely by the coalescence of cells, which send off prolongations in various directions, in the manner of stellate pigment-cells, such as those seen at *c*, *c*, Fig. 66. By the junction of these prolongations, a network of tubes is formed, which is at first very irregular in its character; the greatest diameter of the tubes being in the situation of the centres or bodies of the original cells; whilst between these, at the points where their prolongations coalesced, they are much contracted. The calibre of the vessels, however, gradually becomes equalised, and the

network becomes connected with the larger trunks, and bears a part in the general circulation.—Appearances indicative of a similar process have been observed by Prof. Kölliker* in the tail of the very young Tadpole, at the time when it is undergoing rapid increase. The first lateral vessels

FIG. 67.


*Capillary Blood-vessels* from Pia Mater:—*a*, calibre of the tube, partly occupied by oval nuclei, alternately arranged lengthways, and epithelial in their character; *b*, *b*, *b*, nuclei projecting on the exterior of the tube; *c*, *c*, walls, and *d*, calibre, of a large branch; *f*, *f*, oval nuclei, arranged transversely. Magnified 410 diameters.

of the tail have the form of simple arches, passing between the main artery and vein, and are produced by the junction of prolongations shot forth from these vessels, with similar prolongations from stellate or caudate cells in the substance of the tail (Fig. 68). Some of the latter, again, coalesce with those of other cells; so that an irregular network is produced, which communicates with the previously-formed trunks. The cavities of these cells and of their radiations (which are at first so fine as to be almost impervious), having coalesced, they begin to receive fluid from the vessels, then enlarge, and finally appear as continuations of them. The observations of Messrs. Paget and Kirkes† on the development of blood-vessels in the fine gelatinous tissue conveying the umbilical vessels of the embryo-sheep to the uterine cotyledons, lead to a very similar idea of the process; for here, also, there may be seen chains and networks of cells of various shapes, some fusiform, some stellate, some round or oval with thread-like prolongations, connected to each other and to the adjacent blood-vessels by very slender prolongations, which gradually enlarge, and become filled with blood from the vessels with which they come into communication. Some of the appearances noticed by

* "Annales des Sciences Naturelles," Zool., Août, 1846.
† "Supplement to Prof. Müller's Elements of Physiology," pp. 104, 105.

these observers, however, indicate that blood-corpuscles may be formed in parts of this network which have not yet come into connection with the neighbouring vessels, and from other materials than those directly derived from their contents; for coloured nucleated blood-corpuscles were observed in distended parts of the narrowest tubes, which were connected at either extremity, either with blood-vessels, or with other elongated cells, by filamentous prolongations far too fine to transmit particles of the size of blood-corpuscles.

295. Some observations have been recently adduced by Dr. W. T. Gairdner,* which indicate that this independent formation of blood-vessels and of blood may take place (as John Hunter maintained, and as many others have since asserted, though without adequate evidence,) to a yet greater extent. The case was one in which a false membrane had been formed, within the arachnoid cavity, apparently by the organization of a clot of blood that had been effused in consequence of injury; and it exhibited a large varicose blood-channel, which had no very definite wall, with a great number of smaller branching vessels, having very distinct parietes. The blood of the large channel presented blood-corpuscles of all dimensions, from the smallest appreciable size to that of the fully-formed disk; those of the inferior or intermediate sizes being decidedly more numerous than in ordinary blood. Combining these two facts, therefore,—the relatively *low* state of development of the *largest* channel, and the *young* condition of the blood which it contained, — there scarcely appears room for doubt that the whole plexus was of independent origin, and was not derived from the adjacent blood-vessels. — On the other hand, it seems at least equally certain that in the production of new parts for the repair of injuries, the tissue ordinarily becomes supplied with blood-vessels, not by any such independent formation in its own substance, but by mere out-growth from the capillaries of the subjacent structure. "The vessel," according to the description of Mr. Paget,† "will first present a

Fig. 68.


Formation of *Capillaries* in tail of Tadpole:— *a, a,* capillaries permeable to blood; *b, b,* fat granules attached to the walls of the vessels, and concealing the nuclei; *c,* hollow prolongation of a capillary ending in a point; *d,* a branching cell, with nucleus and fat-granules, communicating by three branches with capillaries already formed; *e,* blood-corpuscles, still containing granules of fat.

* "Edinburgh Monthly Journal," October, 1851, pp. 392–4.

† 'Lectures on Repair and Reproduction,' in "Med. Gaz.," July 13, 1849, p. 71.

slight dilatation in one, and coincidently, or shortly after, in another point; as if its wall yielded a little near the edge or surface. The slight pouches thus formed gradually extend, as fluid canals or diverticula, from the original vessel; still directing their course towards the edge or surface of the new material, and crowded with corpuscles, which are pushed into them from the main stream. Still extending, they converge; they meet; the partition-wall, that is at first formed by the meeting of their closed ends, clears away, and a perfect arched tube is formed; through which the blood, diverging from the main or former stream, and then rejoining it, may be continuously propelled." Sometimes the projecting pouch in which the new vessel originates, gives way, and the blood-corpuscles escape into the substance of the parenchyma; at first they lie there in a confused cluster; but before long they manifest a definite direction, and the cluster bends towards the line in which the new vessel might have formed, and thus opens into the other portion of the arch, or into some adjacent vessel.* This formation of new passages in a determinate direction by a process of 'channelling,' indicates the existence of forces in the parenchyma itself, that determine the direction in which the vessels shall prolong themselves, when the new passage is formed by their outgrowth; in fact it would not seem improbable that this outgrowth is itself but a sort of varicose dilatation, consequent upon the breaking-down of the tissue into which it extends itself. And it is conformable to this view, that, according to the observations of Mr. Travers,† when a new capillary arch is formed by outgrowth, it does not at once convey a stream of blood; but isolated corpuscles enter it, and perform an oscillating movement for some hours, before any series of them passes into it; so that we cannot regard the new canal as formed by the *vis a tergo* of the circulating blood, as some have maintained it to be.

296. The structure of the minutest *Absorbent* vessels is very similar to that of the capillary Blood-vessels. Both in the substance of the tissues in which the *lymphatics* take their origin, and in the extremities of the intestinal villi in which are the radicles of the *lacteals*, they seem to originate in plexuses; which, however, are unlike those of the capillary blood-vessels, in communicating with trunks on one side only. These plexuses are formed, according to the observations of Prof. Kölliker (loc. cit.), on the same original plan with those of the blood-vessels; namely, by the junction and fusion of processes from stellate cells, either with each other, or with off-shoots from previously-existing vessels. In the development of the lymphatic tubuli, however, the union of the cells is in a more simple linear direction, than it is in the production of capillaries; the anastomosis of the former, in their complete state, being much more rare than that of the latter.

### 6. *Of the Muscular Tissue.*

297. The Muscular tissue, which is the instrument of the performance of all the sensible movements of the body, exists under two forms;—the ultimate fibres being marked in one by *transverse* and *longitudinal striæ;*

* Paget, Op. cit. p. 72.

† "Physiology of Inflammation and the Healing Process," p. 77.

—whilst in the other they are *plain, smooth,* or *unstriped.* The former is chiefly concerned in the various movements which are effected through the agency of the Nervous system, and which are connected with the peculiarly Animal powers of the being. The latter is with difficulty called into action through the nervous system, but is much more readily excited by stimuli applied to itself; and this is employed to perform various movements, which are more immediately concerned in the Vegetative or Organic functions.—By some, the two forms of tissue have been spoken of as those of 'voluntary' and of 'involuntary' muscle: but this distinction is not correct; since every muscle ordinarily termed voluntary may be called into action involuntarily, and the Heart, which is a purely 'involuntary' muscle, has the striated fibre characteristic of the 'voluntary.'

298. When we examine an ordinary Muscle (from one of the extremities for example) with the naked eye, we observe that it presents a fibrous appearance; and that the fibres are arranged with great regularity, in the direction in which the muscle is to act. Upon further examination it is found, that these fibres are arranged in *fasciculi* or bundles of larger or smaller size, connected by means of areolar tissue; and when the Microscope is applied to the smallest fibre which can be seen with the naked eye, it is seen itself to consist of a fasciculus, composed of a number of cylindrical fibres lying in a parallel direction, and closely bound together. These primitive fibres present two sets of markings or *striæ;* one set *longitudinal,* the other *transverse* or annular. By more closely examining these *fibres,* when separated from each other, it is frequently seen that each may be resolved into *fibrillæ,* by the splitting of its contents in a *longitudinal* direction, as shown in Fig. 69. These fibrillæ have a peculiar

Fig. 69.

Fasciculus of *Striated Muscular Fibres;* the fibres separated at one end into brush-like bundles of *fibrillæ.*

Fig. 70.

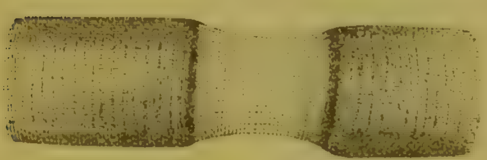
Portion of *Striated Muscular Fibre* separating into disks, by cleavage in direction of transverse striæ.

*beaded* appearance, which will be presently noticed more particularly.—It not unfrequently happens, however, that when a fibre is drawn apart, its contents separate in the direction of the *transverse* striæ; forming a series of *disks,* as shown in Fig. 70. This cleavage is just as natural as the former, though less frequent; and it leads us to a view of the composition

of Muscular Fibre, somewhat different from the one commonly adopted. To use the words of Mr. Bowman,* it would be as proper to say, "that the fibre is a pile of *disks*, as that it is a bundle of *fibrillæ;* but in fact it is neither the one nor the other, but a mass in whose structure there is an intimation of the existence of both, and a tendency to cleave in the two directions. If there were a general disintegration along all the lines in both directions, there would result a series of particles, which may be termed *primitive particles* or *sarcous elements,* the union of which constitutes the mass of the fibre. These elementary particles are arranged and united together in the two directions. All the resulting discs, as well as fibrillæ, are equal to one another in size; and contain an equal number of particles. The same particles compose both. To detach an entire fibrilla, is to abstract a particle of every disc; and *vice versâ.*"

299. The elements of Muscular Fibre are bound together, in the perfect condition of the fibre, by a very delicate tubular sheath. This cannot always be readily brought into view; but it is occasionally seen with great distinctness: thus, when the two ends of a fibre are drawn apart, its contents will sometimes separate without the rupture of the sheath, which then becomes evident (Fig. 71); and this, during the act of contraction, may sometimes be observed to rise up in wrinkles upon the surface of the fibre, as seen in Fig. 75. This sheath is quite distinct from the areolar tissue, which binds the fibres into fasciculi; and it has been termed, for the sake of distinction, the *Myolemma.* Its existence may be demonstrated in any Muscular fibre, by subjecting it to the action of fluids which occasion a swelling of its contents; this is especially the effect of acids and alkalies, and may be well produced by the citric and tartaric acids, and by potash. For a time, the Myolemma yields to the distention which takes place from within; but at last it bursts at particular points, and a sort of hernia of its contents takes place, making the existence of a perfect envelope in all other parts quite evident. This membrane is itself perfectly transparent, and has nothing to do with the production of either the longitudinal or the transverse striæ. There is no reason to believe that it is perforated either by nerves or by capillary vessels; in fact, it seems to be an effectual barrier between the real elements of Muscular structure, and the surrounding parts. That it has no share in the contraction of the fibre, is evident from the fact just mentioned, respecting the condition which it occasionally presents when the fibre is much shortened.

Fig. 71.



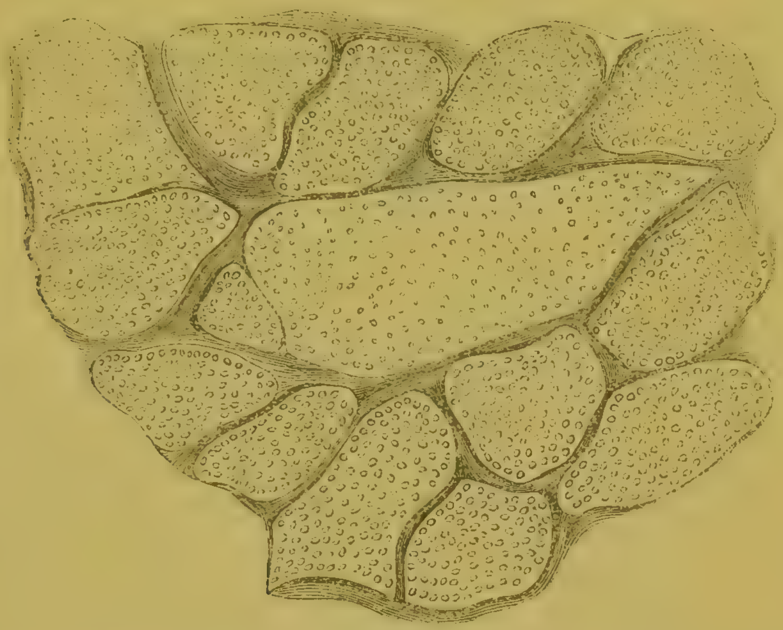
Muscular Fibre broken across, showing the untorn *Myolemma* connecting the fragments.

300. Muscular Fibres are commonly described as cylindrical; but there is reason to believe that they are rather of a polygonal form, their sides being flattened against those of adjoining fibres (Fig. 72). In some instances the angles are sharp and decided; in others they are rounded off, so as to leave spaces between the contiguous fibres for the passage of vessels. The average diameter of the fibres in Man is stated by Mr. Bowman (loc. cit.)

* 'On the Minute Structure and Movements of Voluntary Muscle,' in "Philosophical Transactions," 1840.

at about 1-400th of an inch; being about 1-352nd of an inch in the male, and 1-454th of an inch in the female. He has met with extremes, however, as wide apart as 1-507th and 1-192nd of an inch in the male; and 1-615th and 1-384th of an inch in the female. The average distance between the striæ is about 1-9400th of an inch; but it is sometimes only

FIG. 72.

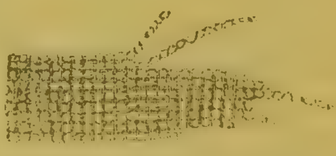


Transverse section of *Muscular Fibres*, from pectoral muscle of Teal; showing the irregular form of the fibres, and the aggregation of circular particles, with which they are completely filled.

1-15,000th, and sometimes as much as 1-6000th, varying with the state of contraction or relaxation of the fibre.*—It has been maintained by some that each Muscular fibre is a *hollow* bundle of fibrillæ; but the appearance presented by transverse sections proves that this is not the case, the whole area of the tube being occupied by fibrillæ, without any trace of central cavity. The extremities of the cut fibrillæ, however, cannot always be distinguished in Mammalia, in consequence, as it would seem, of their close and intimate lateral union; but they are very evident in Birds, Reptiles, and Fishes (Fig. 72). The addition of an acid increases the distinctness of the fibrillæ, by widening the interstices between them.

301. When the *fibrillæ* are separately examined, they are found to present an alternation of dark and light spaces, corresponding with the transverse striæ of the fibre, and the lighter intervals between them. It is this alternation, which gives to the fibrillæ the beaded appearance they present, when their outline is not perfectly seen (Fig. 73). When well-prepared specimens, however, are carefully examined under a sufficient magnifying and good defining power, it is seen that the border of the fibrillæ is straight or

FIG. 73.



Fragment of Muscular Fibre from macerated heart of Ox, showing *formation of striæ* by the aggregation of fibrillæ.

* It is curious that whilst the diameter of the *fibres* varies considerably in different animals, being generally much greater in the cold-blooded than in the warm-blooded tribes (corresponding with the larger size of the blood-disks of the former), the diameter of the *fibrillæ*, and the distance of the striæ from each other, vary extremely little.

nearly so; the beaded appearance being an optical illusion. Moreover, each of the light spaces is seen to be crossed by a delicate but distinct line, separating it into two equal parts; and upon attentive examination it is seen, that a transparent border, equal in breadth to either of these parts, exists at the *sides*, as well as between the *ends*, of the dark spaces (Fig. 94). Thus each dark space is completely surrounded by this pellucid border; and it can scarcely be doubted that the whole constitutes a complete though minute *cell*, and that the entire fibrilla is made up of a linear aggregation of such cells.* When the fibril is in a state of relaxation, as seen at *a*, the diameter of the cells is greatest in the longitudinal direction; but when it is contracted, the fibril increases in diameter as it diminishes in length; so that the transverse diameter of each cell equals or even exceeds the longitudinal diameter, as seen at *b*. The difference between the two states is frequently much more striking than is represented in the figure. —Thus the act of Muscular contraction seems to consist in a change of form in the cells of the ultimate fibrillæ, which must be regarded as a manifestation of forces in their interior, that have been developed in previous acts of Nutrition (§ 110); and it thus corresponds very closely with the contraction of certain Vegetable tissues, of which the component cells change their form when irritated, and thus produce a movement.† The essential difference, therefore, between the striated muscular tissue of Animals, and the contractile tissues of Plants, consists in the subjection of the former to Nervous influence.—The diameter of the ultimate fibrillæ, and the length of the component cells, will of course vary according to the contracted or relaxed condition of the fibre; but they otherwise seem to be tolerably

Fig. 74.


Structure of the *ultimate fibrillæ* of Striated Muscular Fibre: — *a*, a fibril in a state of ordinary relaxation; *b*, a fibril in a state of partial contraction.

* This account of the ultimate structure of Muscular Fibre was first published simultaneously (March, 1846), by the Author of this Treatise, in his "Manual of Physiology," and by Dr. Sharpey in his new edition of Dr. Quain's "Elements of Anatomy." Both of these statements, which were completely independent of each other, were founded upon the examination of the very beautiful preparations of Muscular Fibre, made by Mr. Lealand the Optician; who appears to have been the first to direct attention to the transverse line dividing the bright space, and to the bright border edging the dark spot. A similar delineation had previously been published, however, by Dr. Goodfellow ("Physiological Journal," No. iv.); but his interpretation of the appearances was altogether different; for he considered the dark spaces as the "sarcous elements" of Mr. Bowman, and regarded them as separately inclosed within partitions formed by internal prolongations of the general investing Myolemma. By Mr. Erasmus Wilson, again, the appearances were described as leading to the belief that two kinds of cells exist in each fibrilla, a dark and a light; *a pair* of light cells, separated by the delicate transverse line just spoken of, being interposed between each pair of dark ones ("Manual of Anatomy," 3rd edit. p. 162). The bright edging to the dark spots was overlooked by him.—The view taken by Dr. Sharpey and the Author has the entire concurrence of several of the most eminent Microscopists in London and elsewhere (see, for example, Mr. Quekett's "Practical Treatise on the Use of the Microscope," 2nd edit., pl. ix., fig. 12); and testimony in its favour has been given by some, who, before they saw the preparations which afford the evidence of its truth, had entirely discredited it. (See Dr. Hassall's "Microscopic Anatomy," pp. 341, 548.)

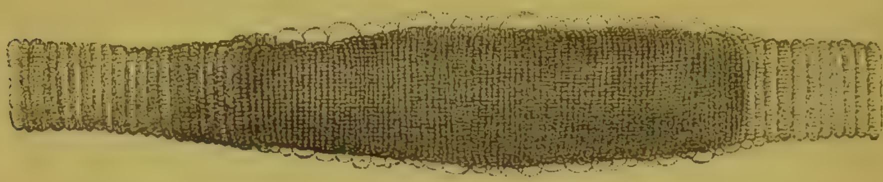
† See "Princ. of Phys., Gen. and Comp.," § 138, and CHAP. XIX.

uniform in different animals. The average diameter may be stated at about 1-10,000th of an inch; but it has been observed as high as 1-5000th, and as low as 1-20,000th, even when not put upon the stretch. The length of the component cells corresponds, of course, to the distance of the striæ on the entire fibre; and this also has been just shown to average about 1-10,000th of an inch.

302. The general opinion as to the disposition of the fibres during the contraction of Muscle, was for a long period that of Prevost and Dumas, who stated that they were thrown into a sinuous or zig-zag flexure. More recent observations, however, have fully demonstrated the incorrectness of this view; the improbability of which might have been suspected from the consideration, that fibres in this state of flexure could scarcely be imagined to be exerting any force of traction. Prof. Owen has noticed that, in the contracted state of the very transparent muscles of some Entozoa, each separate fibre, which may be seen with great distinctness, presents a knot or swelling in the middle, besides being generally thickened; but that it is simply shortened, without falling out of the straight line. Dr. Allen Thomson remarked the same thing in the Frog; single fibres, whilst continuing in contraction, being simply shortened, without falling into zig-zag lines: and he was led to suspect, from this and other circumstances, that the zig-zag arrangement was not produced, until the act of contraction had ceased. The inquiries of Mr. Bowman (loc. cit.) have proved most satisfactorily, that, in the state of contraction, there is an approximation of the transverse striæ, and a general shortening of the fibre; and that its diameter is at the same time increased; but that it is never thrown out of the straight line, except when it has ceased to contract, and its two extremities are still held in proximity by the contraction of other fibres. The whole process may be distinctly seen under the Microscope, in a single fibre isolated from the rest: it is, of course desirable to select the specimen from those animals, in which the contractility of the Muscle is retained for the longest period after death,—which is particularly the case in Reptiles among Vertebrata, and in most Invertebrata (Mr. Bowman particularly recommends the Crab and Lobster); but the change has been fully proved to differ in no essential degree, in the warm-blooded Vertebrata. The contraction usually commences at the extremities of the fibre; but it frequently occurs also at one or more intermediate points. The first appearance is a spot more opaque than the rest, caused by the approximation of a few of the dark points of some of the fibrillæ: this spot usually extends in a short time through the whole diameter of the fibre; and the shading, caused by the approximation of the transverse striæ, increases in intensity. The striæ are found to be two, three, or even four times as numerous, in the contracted, as in the uncontracted part; and are also proportionally narrower and more delicate. The line of demarcation between the contracted and uncontracted portions is well defined; but, as the process goes on, fresh striæ are absorbed (as it were) from the latter into the former. The contracted part augments in thickness; but not in a degree commensurate with its diminished length; so that its solid parts lie in smaller compass than before,—the fluid which previously intervened between them, being pressed out in bullæ under the myolemma (Fig. 75). The force with which the elements of the fibre thus tend to approximate, is evidently

considerable; for if the two extremities be held apart, the fibre is not unfrequently ruptured. This corresponds with the appearances found in the muscles of persons who have died from tetanus; for in the ruptured fibres of those muscles, which have been the subjects of the spasmodic action, the striæ have been observed to approximate so closely, as to be

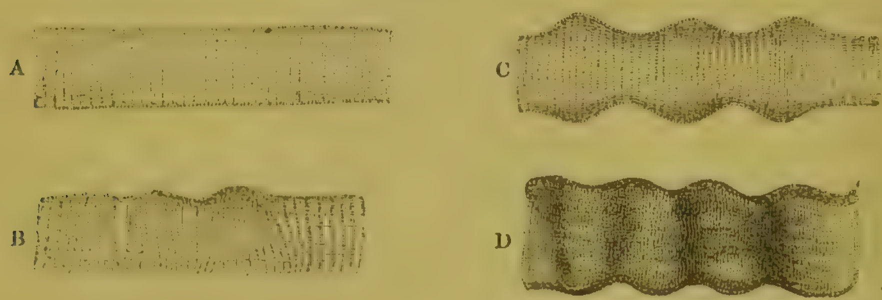
FIG. 75.



Muscular Fibre of Dytiscus, showing the *contracted state* in the centre; the striæ approximated; the breadth of the fibre increased; and the myolemma raised in bullæ on its surface.

scarcely distinguishable. When the contraction is not very decided, the dark and elevated spot appears to play like a wave along the fibre, before it involves the whole diameter in any part (Fig. 76, B); and even when considerable traction is being exercised, there is continual interchange in

FIG. 6.




Muscular Fibre of Skate, in a state of *rest* (A), and in *three different stages of contraction* (B, C, D).

the elements by which it is effected,—the disks at one end of the contracted part receding from each other, whilst at the other end new disks are being received into it.

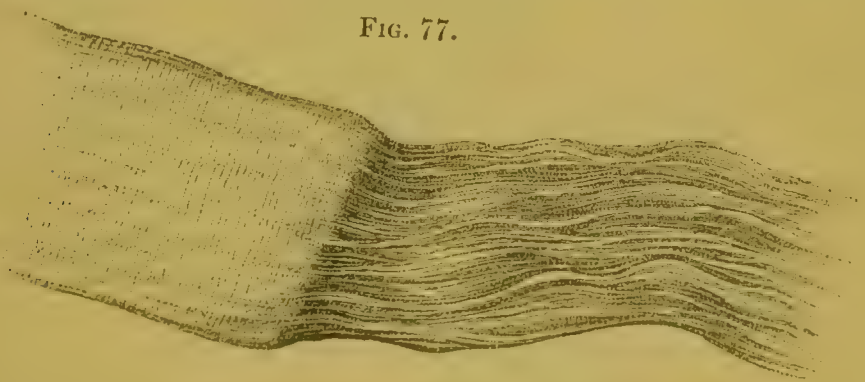
303. The foregoing description is chiefly derived from the appearances presented by Muscular Fibre, when spontaneously passing into that state of contraction which is termed the *rigor mortis* (§ 333); but there can be no reasonable doubt, that the phenomena of contraction, excited by the agency of the nerves, are precisely similar. Mr. Bowman has remarked, that stimuli of various kinds, directly applied to them, produce corresponding effects, although, in the case of galvanism, the change is too rapid for its steps to be followed; and that, from the appearances presented by muscles which have been affected with tetanic spasms, the contraction produced by nervous agency may be inferred to correspond in character.—The zig-zag arrangement which is so often seen in the fibres, may be easily produced, by approximating the ends of a fasciculus, after the irritability of its fibres has ceased;* and seems to be that into which

* Mr. Bowman's conclusions have been since confirmed by Prof. E. Weber ("Archives d'Anatomie Générale," Jan. 1846), and by other observers.

bres are naturally thrown, if, on elongation following contraction, they re not at once stretched by antagonist muscles. Many facts support he opinion, that, when an entire muscle is contracting, all its fasciculi re not in contraction at once; but that there is a continual interchange 1 the parts by which the tension is effected, some relaxing whilst others re shortening. On examining a muscle of which some fasciculi present he zig-zag arrangement, others will be seen (if the two extremities have ot been purposely approximated) to be quite straight, and in a state of ontraction; and the former appearance seems to be presented by bundles f fibres, which have either not yet entered into contraction, or which ave relaxed after undergoing it, but of which the extremities are still pproximated by the agency of other contracting fibres. Again, the *sound* mitted by a muscle in vigorous contraction, indicates a continual move- nent among its particles (§ 330). And the great excess of force put orth, when from any cause an unusual amount of nervous power is deter- nined to a muscle (as in violent passion or mania, or in those peculiar tates of abstraction in which the attention can be entirely concentrated pon any one part), above that which an ordinary voluntary effort can voke, clearly indicates that, in the latter case, only a part of the muscle an be in action at once, which seems to be attributable to this constant novement of its substance.—The result of various experiments made for he purpose, leads to the conclusion, that the total bulk of a muscle in ontraction is not less than when it is in a relaxed state; or that the ifference, if any exist, is extremely trifling.

304. Every Muscular Fibre, of the striated kind at least, is attached t its extremities to white fibrous tissue; through the medium of which, exerts its contractile power on the bone or other substance which it is estined to move. The whole fasciculus of fibrillæ sometimes ends bruptly in a perfect disk; but not unfrequently the extremities of the bres become rounded or conical, in consequence of the prolongation of ertain fibrillæ beyond others. Prof. Kölliker describes the terminal brillæ as occasionally losing their transverse striæ, and as passing with pparent continuity into the fibrils of the tendon, the myolemma not eing continued over the extremity of the fibres; but it has always ap- eared to the Author, that the connection between the muscle and the

Fig. 77.



*Attachment of Tendon* to Muscular Fibre, in Skate.

endon is established rather through the medium of the myolemma than hrough that of the fibrillæ. Where the muscular fibre terminates in a road flat disc (Fig. 77), the tendinous fibres appear at first to stop short

upon its surface; but a more careful examination will generally enable them to be traced over the myolemma of the cylindrical portion of the fibre; and the Author has occasionally seen indications of a double spiral arrangement of these fibres around the sheath of the muscular fibre, which has also been described by Dr. Leidy. When the fibres of a muscle are inserted more or less obliquely into the side of a tendon whose fibres take a different direction, the muscular fibres are attached by rounded or blunt conical ends to the side of the tendinous fasciculi, which are excavated into little shallow pits or dimples to receive them; and the continuity of the myolemma over their extremities can then be distinctly made out.

305. The *plain*, *smooth*, or *non-striated* form of Muscular tissue, ordinarily presents itself in the condition of flattened bands, whose diameter is usually between 1-2000th and 1-3000th of an inch; their substance is translucent, but sometimes finely granular; and they are usually marked at intervals by peculiar elongated nuclei, which, when not originally visible, may be rendered so by acetic acid (Fig. 78). These bands are generally collected into fasciculi, in which they lie parallel with one another; but the fasciculi themselves often cross each other and interlace. They have not, as a general rule, fixed points of attachment, like those of the muscles composed of striated fibres; but form continuous investments around cavities lined by mucous or other membranes, as the alimentary canal, the uterus, the bladder, the vascular trunks, &c.; or are dispersed through the substance of other fibrous tissues, especially the skin, to which they impart a contractile property.—This tissue however, has, lately been resolved by Prof. Kölliker * into a yet more elementary form; for he has shown that every so-called fibre is either a single elongated cell, or is a fasciculus of such cells; each cell having an elongated staff-like nucleus, which is one of its most distinctive characters. Three principal forms of such cells are described by him:—1st. Short, rounded, fusiform, or nearly rectangular plates, like those of epithelium, about 1-1125th of an inch long, and 1-1875th of an inch broad:—2nd. Long plates of irregular rectangular, fusiform, or club shape, with fringed edges, about 1-562nd of an inch long, and 1-3750th of an inch broad:—3rd. Long, narrow, fusiform, round, or flattened fibres, with pointed terminations (Fig. 79), which are either straight or wavy, from about 1-612th to 1-50th of an inch long, and from 1-5625th to 1-1125th of an inch in breadth. The first and second of these forms are only found in the walls of the blood-vessels; and the first may be easily mistaken for the cells of epithelium; the last form is the one which presents itself everywhere else.

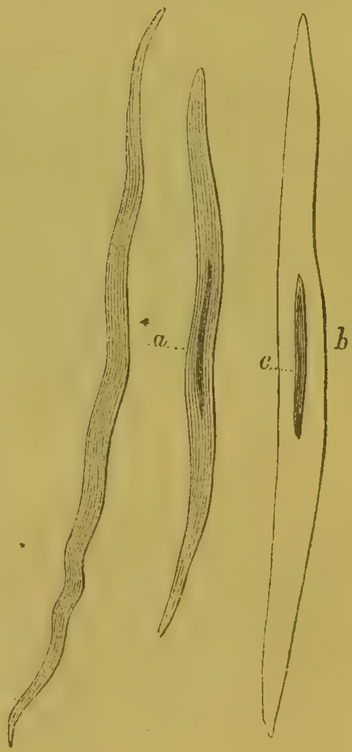
FIG. 78.


*Non-striated Muscular Fibre*; at *b*, in its natural state; at *a*, showing the nuclei after the action of acetic acid.

* "Kölliker and Siebold's Zeitschrift," 1849.

These muscular fibre-cells are composed of a soft yellow substance, which wells in water and acetic acid, in which last it becomes of a paler colour. There is no appreciable difference between the outer and inner parts; hough when treated with acetic acid it would seem as if each fibre-cell had . delicate covering. Their substance is homo-;eneous, with faint longitudinal striations; and hey often contain small pale granules, some-.imes yellow globules of fatty matter. Each ibre-cell has a pale nucleus (sometimes only perceptible when it is treated with acetic .cid, *b*), which constitutes its most distinctive character. Its form is peculiar, being like a taff rounded at each end (*c*); its substance is homogeneous; its length from 1-2800th to .-1875th of an inch; and its breadth from about 1-25,000th to 1-14,000th of an inch.—The muscles composed of this form of tissue nay be divided (according to Prof. Kölliker) nto (A) the *pure* smooth muscles, which con-ain no other kind of tissue, such as those of he nipple, the corium, the interior of the eye, he intestinal canal, the bladder, the prostate, he vagina, the smaller arteries, veins, and ymphatics; and (B), the *mixed* smooth mus-cles, which contain, besides the muscular fibre-cells, areolar tissue, and elastic fibres; such are the trabeculæ of the spleen and corpora cavernosa, the dartos, the circular fibres of the arger arteries and veins, the long and trans-verse fibres of the urethra, prostatic duct, Fallopian tubes, and uterus; and in the tra-chea, bronchi, urethra, inner muscular layer of the testicles, seminal ducts, &c., they change by imperceptible degrees into the first form.

Fig. 79.




Fusiform cells of *Smooth Muscular Fibre*, from the renal vein of Man:—*a*, two cells in their natural state, one of them showing the staff-shaped nucleus; *b*, a cell treated with acetic acid, with its nucleus *c* brought strongly into view.

306. The muscular structure of the Heart is peculiar, in presenting the general arrangement of the non-striated muscles, as regards the interlace-ment of the fasciculi and the absence of fixed points of attachment, with the ultimate structure of the striated. The fibres are of smaller diameter, however, than those of the voluntary muscles; and the striæ are less strongly marked, and are less regular. In the heart, too, is seen more frequently than elsewhere, the subdivision and anastomosis of the mus-cular fibres; which, first observed by Prof. Kölliker (in 1849) in the heart of the frog, has been witnessed by the same distinguished anatomist in the cardiac fibres of Man and of various among the higher animals.—No proper gradation can be anywhere traced from the striated to the non-striated form; but the two sometimes come into very close apposition, as where the constrictors of the pharynx overlie the muscular coat of the œsophagus itself.*

* The distinctness of the two kinds of tissue is curiously marked in the case of the para-sitic *Trichina spiralis*, which infests the striated-fibre muscles alone, and may be seen to stop short at the margin of the inferior constrictor, without passing on to the tissue beneath.

307. The Chemical Composition of Muscular Fibre seems to be very uniform, from whatever source it is obtained. It is impossible, however, to determine it with precision; on account of the difficulty of completely isolating the substance of the fibres from the areolar tissue, vessels, and nerves, that are blended with them. The proper muscular substance differs from the simple fibrous tissues, in not being resolvable into gelatin by the prolonged action of boiling water; and in being soluble in acetic acid, from which it is precipitated by ferrocyanide of potassium, showing that it belongs to the proteine-compounds. It is not, however, true Fibrin, but corresponds rather to coagulated Albumen (§§ 21, 25). The following analysis of Muscle by Berzelius corresponds very exactly with those since made by Braconnet, Schultz, Marchand, and other Chemists:—

| | |
|---|---|
| Proper Muscular substance | 15·80 |
| Gelatin (from areolar tissues) | 1·90 |
| Albumen and hæmatin | 2·20 |
| Phosphate of lime, with albumen | ·08 |
| Alcoholic extract, with salts (lactates ?) | 1·80 |
| Watery extract, with salts | 1·05 |
| Water, and loss | 77·17 |
| | 100·00 |

Thus something less than 23 per cent of solid matter exists in ordinary meat; and in 100 parts of this solid matter, there are about 3½ parts of fixed salts.—The close correspondence in ultimate composition, between dried Muscle, and dried Blood, according to the analyses of Playfair and Böckmann, is not a little remarkable. The following are their results:—

| | Playfair. | | Böckmann. | |
|---|---|---|---|---|
| | *Muscle.* | *Blood.* | *Muscle.* | *Blood.* |
| Carbon | 51·83 | 51·95 | 51·89 | 51·96 |
| Hydrogen | 7·57 | 7·17 | 7·59 | 7·33 |
| Nitrogen | 15·01 | 15·07 | 15·05 | 15·08 |
| Oxygen | 21·36 | 21·39 | 21·24 | 21·21 |
| Ashes | 4·23 | 4·42 | 4·23 | 4·42 |

The nature of the *saline* constituents of Muscle, however, indicates its relation to be rather with the contents of the *Corpuscles*, than with the Blood as a whole (§ 140); for the per-centage composition of the entire Ash is,—chloride of potassium 14·8, phosphoric acid 36·6, sulphuric acid 2·9, potash 40·2, and earths with oxide of iron 5·6.—Some very interesting researches have been made by Helmholtz,* on the chemical changes induced in the tissue by Muscular action. Powerful contractions were induced by electricity in the amputated leg of a Frog, and were kept up as long as the irritability was retained: the flesh of the two limbs was then analysed; and it was found that, in every instance, the water-extractive was diminished in the electrized muscle, to the extent of from 20 to 24 per cent, whilst the alcoholic extract was increased to about the same amount. Similar results were obtained from experiments on warm-blooded animals; the amount of change, however, being less, on account of the shorter duration of their muscular irritability. It may be expected that more exact analyses will unequivocally indicate the production of an augmented

* Müller's "Archiv.," 1845.

ımount of those products, which we know to result from the retrograde netamorphosis of the muscular substance, consequent upon its functional ıctivity (§§ 52—62).

308. Muscular tissue, properly so called, is as extra-vascular as cartilage ›r dentine; for its fibres are not penetrated by vessels; and the nutriment equired for the growth of its contained matter must be drawn by absorp-ion through the myolemma. But the substance of Muscle, as a whole, s extremely vascular, the Capillary vessels ›eing distributed in parallel lines, united ›y transverse branches, in the minute in-erspaces between the fibres (Fig. 80); so hat it is probable that there is no fibre, vhich is not in close relation with a capil-ary. The number of blood-vessels in a ;iven space will of course be greater, where he fibres and the capillaries are both mall, as in Mammals and Birds, than ;here they are of larger diameter, as in Reptiles and Fishes; and the former con-ition will obviously be the one most favourable to the performance of ctive changes between the blood and the muscle. These changes consist, ; would appear, not merely in the nutrition of the tissue; but in the sup-ly of oxygen, which is a necessary condition of the excitement of its activity. Ve shall hereafter see, indeed, that every muscular contraction probably ıvolves the disintegration of a certain amount of its substance, through ıe union of oxygen, supplied by arterial blood, with its elements; and ıat the great demand for nutrition, which is occasioned by muscular ctivity, is for the purpose of repairing this loss. The muscles of warm-looded animals speedily lose their irritability, after the supply of arterial lood has been suspended, either through the cessation of the general rculation, or by deficient aeration of the fluid. But the muscles of cold-looded animals, which are very inferior in the energy and rapidity of ıeir action, preserve their properties for a much longer period, after the eprivation of their supply of arterial blood; in accordance with the eneral principle, that, the lower the usual amount of vital energy, the nger is its persistence, after the withdrawal of the conditions on which it dependent. The very indisposition to a change of composition, on hich the less ready action depends, produces a longer retention of the ›wer of acting. — Much discrepancy of opinion has existed amongst ıatomists, as to the presence of Lymphatics in Muscular tissue. The icroscopic inquiries of Prof. Kölliker incline him to the opinion that ıe small muscles are destitute of absorbents, and that the few lymphatics hich seem to issue from some of the larger Muscles, belong to their areolar ıeath and its larger subdivisions.

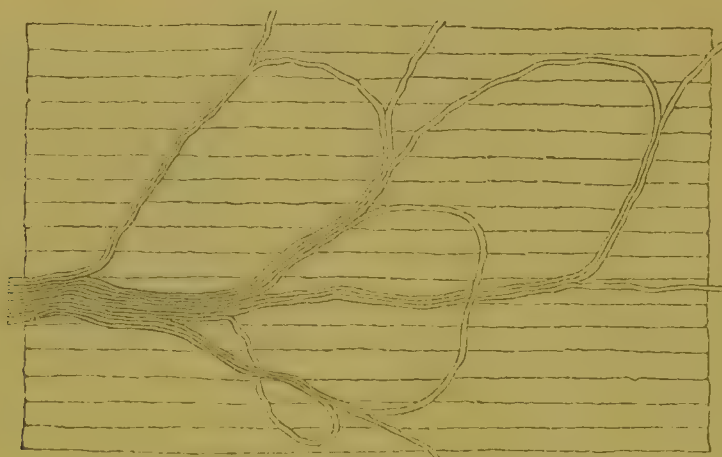
FIG. 80.

*Capillary net-work* of Muscle.

309. The Striated Muscles (excepting the Heart) are, of all the tissues cept the skin, those most copiously supplied with Nerves. These, like e blood-vessels, lie on the outside of the Myolemma of the several fibres; ıd their influence must consequently be excited through it. The general rangement of these nerves is shown in Fig. 81. Their ultimate fibres tubes cannot be said to *terminate* anywhere in the Muscular substance; r, after issuing from the trunks, they form a series of loops, which

return either to the same trunk, or to an adjacent one. The occasional appearance of a termination to a nervous fibril is caused by its dipping down between the muscular fibres, to pass towards another stratum.* The nerves are almost exclusively of the motor kind; but a few sensory are blended with them. We see this most clearly in cases, in which the motor and sensory trunks supplying the muscles are distinct; as in the

FIG. 81.



Form of the terminating loops of the *Nerves* in the Muscles.

muscles of the orbit.—The non-striated muscles are very sparingly supplied with nerves; and these are derived (for the most part, if not entirely), from the Sympathetic system, rather than from the Cerebro-Spinal.

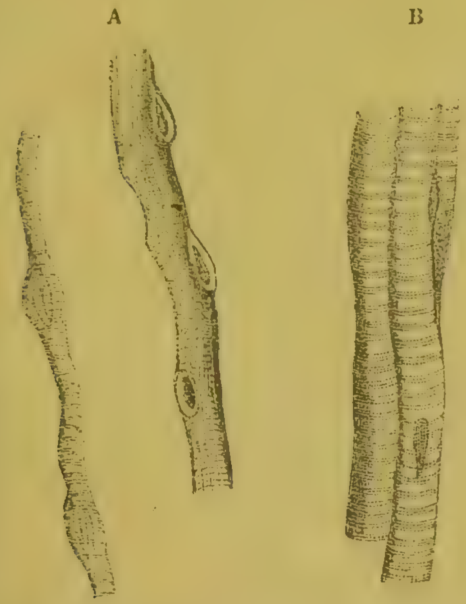
310. The *development* of striated Muscular fibre commences, according to Schwann and Valentin, in the development of a linearly-arranged series of cells from nuclei lying in the midst of a soft blastema. At the points of contact between the cells, the partitions disappear; and thus a continuous tube is formed, which seems to become the myolemma of the fibre. The nuclei of the original cells, however, still remain; and besides these, the tube may be seen to contain a number of granular particles, which gradually (according to the observation of Dr. Sharpey †) come to present a somewhat regular disposition in transverse lines between the nuclei. The full development of the transverse striæ, which indicates the complete evolution of the contained fibrillæ within the myolemma, does not take place until subsequently. For some time, the nuclei continue to be very apparent, in consequence of their projection from the edges of the fibre, and of the smallness of its diameter (Fig. 82); but as the fibre increases in size, they become more imbedded in its substance; and in the muscular fibre of the adult, their presence can only be made evident

* A different method of termination has been discovered by Prof. Wagner in the muscular nerves of the frog, and by Profrs. Müller and Brücke in those of the pike; the ultimate nerve-fibres themselves undergoing subdivision, and ending by exquisitely fine free extremities. But although there is no doubt as to the frequency of that arrangement in cold-blooded Vertebrata, as well as in many Invertebrated animals, yet, from the researches of Prof. Kölliker, it seems certain that the looped arrangement prevails in the muscles of Man and of other Mammalia; and that the subdivision of the nerve-fibres, with the termination of the fibres in free extremities, if it take place at all, is quite exceptional. (See his "Mikroskopische Anatomie," band ii. pp. 238–247.)

† See his Introduction to "Quain's Elements of Anatomy," p. clxxv.

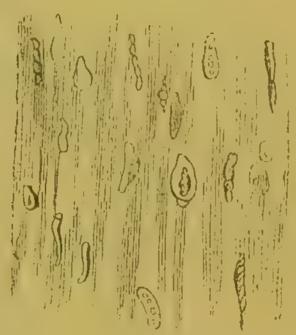
by treating the fibre with weak acids (such as the citric or tartaric), which renders the nuclei more opaque, whilst the surrounding structure becomes more transparent (Fig. 83). They are usually numerous in proportion to the size of the fibre.—The development of the striated fibre

Fig. 82.




Muscular Fibres from *fœtal* pectoralis:—A, from Calf at two months; B, from Human fœtus of nine months.

Fig. 83.



Mass of Muscular Fibres from the pectoralis major of the *Human fœtus*, at nine months. These fibres have been immersed in a solution of tartaric acid; and their numerous corpuscles turned in various directions, some presenting nucleoli, are shown.

has more recently been carefully studied by M. Lebert in the Heart of the Chick.* The rhythmical contractions of this organ become very manifest and regular towards the 36th hour of incubation; nevertheless, it is at this time composed of nothing else than 'organo-plastic globules' or elementary cells imbedded in a granular blastema. Between the fourth and fifth days of incubation are seen in the midst of the mass of globular particles, certain elongated sub-cylindrical bodies, sometimes grouped together in a reticular manner; these bodies, being the first rudiments of the muscular fibres, not merely in the heart, but also in the other striated muscles, are designated by M. Lebert 'myogenic cells.' Between the 7th and 8th days, the 'organo-plastic globules' undergo a considerable diminution, and the muscular substance presents a more complete development. A longitudinal striation shows itself in the contents of the cylinders, which seems partly due to the grouping of the granular particles of which these contents consist; the transverse striations do not show themselves until some time afterwards. Between the 7th and 9th days, the myogenic cells become more regularly cylindrical and their extremities more rounded; the tendinous fasciculi then begin to be visible, enclosing the lower part of the cylinders, without having as yet any direct relation of continuity with them. The interior of the cylinders becomes more regularly striated in the direction of its length; and between the 10th and 12th days, the transverse striæ appear on the surface, and multiply rapidly, becoming at the same time more and more regular. The 'organo-plastic globules,' which at first separated the

* "Annales des Sci. Nat.," Juin, 1849.

primitive cylinders, gradually disappear; the cylinders approach one another; and before the end of embryonic life, they are found to be grouped into fasciculi. M. Lebert has further shown, that different members of the animal kingdom permanently exhibit the Muscular fibre in the different phases of development here described;* and it appears probable that the smooth muscular fibre-cells of Prof. Kölliker are to be regarded as the original 'myogenic cells,' within which no secondary formation has taken place. — There seems every probability that the nuclei of the parent-cells continue to act as 'centres of nutrition' during the whole life of each fibre; furnishing the germs from which the minute secondary cells, that compose the fibrillæ, are developed as they are required. The diameter of the Muscular fibre of the fœtus is not above one-third of that which it possesses in the adult; and as the *size* of their ultimate particles is the same in both cases, their *number* must be greatly multiplied during the growth of the structure. But we shall find reason to believe, that a decay is continually taking place in the component cells, with a rapidity proportional to the functional activity of the Muscle; and their generation, which occurs as constantly when the nutrient operations proceed in their regular course, is probably accomplished by a development from these centres, at the expense of the blood with which the muscle is copiously supplied.

311. The ordinary rate of *Nutrition* of the Muscular tissue, depends upon its functional activity. Every exertion of its vital Contractility involves—there is good reason to believe—a *waste* or *disintegration* of a proportional amount of its substance; the vital force, which previously manifested itself in the acts of growth and development, being now expended in the form of mechanical power; and the living tissue being consequently reduced to the condition of dead matter, and being thus rendered subject to decomposition, which it previously resisted. Of this there is a great variety of evidence. The increase of the demand for food, occasioned by Muscular activity, is an indication that the nutritive operations are excited by it; and the purpose of these can scarcely be anything else, than the reparation of the loss which the Muscle has sustained. Again, it will be hereafter shown (§ 324), that the presence of Oxygen is essential to the continued development of the contractile force; and there is evidence that, in this development, a chemical change is effected in the substance of the Muscle, which is of a nature destructive to its integrity as an organized tissue. For, in the first place, the researches of Helmholtz, just referred to (§ 307), indicate such a change, from the comparative results of Chemical analysis of the muscle, before and after the violent excitement of its contractility; and this is more definitely shown by that increase in the lactic acid (§ 49), and in the creatine and creatinine (§ 61), obtainable from Muscle, which is consequent upon its functional activity. But still more decided evidence is given to the same effect, by the increase in the excretions which is observable after Muscular exertion; and especially by the augmentation of the Carbonic acid set free from the respiratory organs, and by that of the Urea eliminated by the kidneys. The amount of the latter, indeed, may be regarded, *cæteris paribus*, as an approximate indication of the quantity of Muscular tissue

* "Annales des Sci. Nat.," Mars, 1850.

which has undergone disintegration; being increased or diminished, in precise proportion to the degree of exertion, to which the Muscular system has been subjected.—It cannot but be regarded as a probable inference from these facts, that the development of the Contractile force is in some way dependent upon the Chemical change, which seems to be so essential a condition of it; just as the development of the Electric force of the galvanic battery is dependent upon the new Chemical arrangements, which take place between the bodies brought to act upon one another in its trough.

312. The frequently-renewed exercise of Muscles, by producing a determination of blood towards them, occasions an increase in their nutrition; so that a larger amount of new tissue becomes developed, and the muscles are increased in size and vigour. This is true, not only of the whole Muscular system when equally exercised, but also of any particular set of muscles which is more used than another. Of the former we have examples in those, who practise a system of Gymnastics adapted to call the various muscles alike into play; and of the latter, in the limbs of individuals who follow any calling, that habitually requires the exertion of either pair, to the partial exclusion of the other, as the arms of the Smith, or the legs of the Opera-dancer. But this increased nutrition cannot take place, unless an adequate supply of food be afforded; and if the amount of nutritive material be insufficient, the result will be a progressive diminution in the size and power of the muscles; which will manifest itself the more rapidly, as the amount of exertion, and consequently the degree of *waste*, is greater. Nor can it be effected, if the exercise be too constant; for it is during the intervals of repose, that the reparation of the muscular tissue occurs; and the Muscular system, like the Nervous (§ 360), may be worn out by too constant use. The more violent the action, the longer will be the period of subsequent repose required for the reparation of the tissue: and the longest time will of course be requisite, when (as sometimes occurs) the contractility of the muscle is so completely exhausted by excessive stimulation, that no new manifestation of it can be excited. Nevertheless it is certain, that there must be a provision in *some* Muscles, for the continuance of their nutrition during their state of activity; for in no other way could the Heart and Respiratory muscles, which are in unceasing action during the whole of life, be kept in a state fit for the discharge of their functions.

313. But, on the other hand, the Muscular tissue, like all the softer and more decomposable portions of the organized fabric, has a limited term of existence (§ 114); and hence, even if its contractility be not called into exercise, it undergoes a gradual disintegration, so soon as all the nutritive changes of which its component cells are susceptible, have been completed. This change seems to be a necessary consequence of the high temperature of the bodies of warm-blooded animals; for it does not occur with nearly the same rapidity in cold-blooded Animals, nor in the hybernating condition of certain warm-blooded Mammalia; indeed, when the temperature of the body is reduced to within a few degrees of the freezing point, no chemical change seems possible in muscle,—its spontaneous decay, and its vital activity, being alike checked. Now when a Muscle or set of Muscles, in a warm-blooded animal, is reduced to a state of prolonged inactivity, from whatever cause, its supply of blood is dimi-

nished, and its spontaneous decay is not compensated by an equally active renewal; so that, in time, the characters of the structure are changed, and its distinguishing properties are no longer presented. Thus it was found by Dr. John Reid,* that in a rabbit, a portion of whose sciatic nerve had been removed on one side, the muscles of that leg were but very feebly excited to contraction by Galvanism, after the lapse of seven weeks. The change in their nutrition was evident to the eye, and was made equally apparent by the balance. The muscles of the paralysed limb were much smaller, paler, and softer, than the corresponding muscles of the opposite leg; and they scarcely weighed more than half,—being only 170 grains, whilst the others were 327 grains. It was found also, that a perceptible difference existed in the size of the bones of the leg, even after so short an interval had elapsed; the tibia and fibula of the paralysed limb weighing only 81 grains, whilst those of the sound limb weighed 89 grains. On examining the muscular fibres with the microscope, it was found that those of the paralysed leg were considerably smaller than those of the sound limb, and presented a somewhat shrivelled appearance; and that the longitudinal and transverse striæ were much less distinct. So in persons whose lower extremities have been long disused, the muscles first become pale and flabby; their bulk gradually diminishes; their contractile force progressively decreases, and at last departs almost entirely; and their proper structure is replaced by a deposit of fat, intermixed with ordinary fibrous tissue, in which few or no characteristically-striated muscular fibres can be detected. But muscles that have for some time remained in this condition may be gradually brought back to their original state by exercise, provided that the feeblest contractility remains; for every action which they can be made to perform, determines an augmented flow of blood through the tissue, and gives rise to an improvement in its nutrition, which in its turn increases its contractility, and renders it capable of more vigorous action. This principle is of great importance in the treatment of various forms of paralysis (especially the hysterical), in which the muscles are thrown out of use by the suspension of the functional power of the nerves; for, when the latter have recovered their capacity, the muscles refuse obedience to their stimulation, and can only be brought to act by persevering and judiciously-contrived exercise.—But notwithstanding the energy of nutrition in Muscular tissue, the rapid interstitial change which takes place in it when actively exercised, and the complete restoration of its normal constitution after degeneration from disuse, it is doubtful if any true *regeneration* ever takes place in it, when there has been actual loss of substance. Wounds of Muscles are united by Areolar tissue, which gradually becomes condensed; but its fibres never require any degree of contractility.

314. The property of *Contractility* on the application of a stimulus, appears to be limited, in the fully-developed Human organism, to the two forms of Muscular tissue which have been now described; several tissues which exhibit it, and which yet do not present any obvious evidence of muscular structure, having been shown by Prof. Kölliker to contain the

* "Edinburgh Monthly Journal of Medical Science," May, 1841; and "Physiological, Anatomical, and Pathological Researches," p. 10.

fusiform cells which constitute the non-striated fibre. It is characteristic of *Animal* contractility, as distinguished from that which is concerned in producing the sensible movements of Plants, that whilst it is capable of being called into play by stimuli of various kinds (mechanical, chemical, electrical, &c.), which also act upon the Vegetable contractile tissues, yet it is excited in addition by the stimulus of Innervation, that is, by the operation of Nervous force, to which the tissues of Plants are not amenable.* And it is when its peculiar property is *thus* made to display itself, that the Muscular tissue becomes the instrument of the operation of the Nervous system upon the external world, and thus performs an important part in the purely Animal Functions.—The Muscular tissue, however, is not always thus called into activity through the medium of the Nervous system; for it is employed to execute numerous movements, which are immediately connected with the maintenance of the Organic functions, and in which the influence of Innervation seems to be but little concerned; its contractility being excited to action by stimuli directly applied to itself.—The two forms of Muscular tissue, the *striated* and the *non-striated*, are for the most part appropriated to these two purposes respectively; the former being the kind most readily acted-on through the Nervous system, and being invariably employed in the Muscles that are ordinarily called into action by its influence; whilst the latter is with difficulty excited to contraction through the Nervous System, and is usually employed in Muscles whose action is altogether uncontrollable by the will.

315. This general property of Contractility shows itself under two forms, which are alike distinct in the mode of their action, and in the conditions requisite for its excitation.—Its most obvious and striking manifestations present themselves in the Voluntary muscles and in the Heart; which, when in activity, exhibit powerful contractions tending to alternate with relaxations. The modification of contractility which is concerned in producing these, is distinguished as *Irritability.*—On the other hand, we find that the muscles exhibit a tendency to a moderate and permanent contraction, which is not shown by them when they are dead, and which cannot, therefore, be the result of elasticity, or of any simple physical property; and this contraction, instead of being consequent upon stimulation through the nerves, is especially excited by changes of temperature in the tissue itself. This endowment, which seems to exist in the greatest amount in certain forms of the non-striated muscle, is called *Tonicity.*—These two modifications of Muscular Contractility require a separate consideration.

316. *Of Muscular Irritability.*—All Muscular Fibres which are in possession of vital activity, may be caused to contract by stimuli directly applied to themselves; and these stimuli may be of different kinds. The simplest is the contact of a solid substance, especially if it be pointed; thus we may excite contractions in Muscular fibres, by simply touching them with the point of a needle or of a scalpel. Most substances of strong chemical action, such as acids and alkalies, will excite the fibres to contraction, when directly applied to themselves; but the most powerful agent of all is Electricity.—If we irritate mechanically a portion of a

* See "Princ. of Phys., Gen. and Comp.," CHAP. XIX.

muscle composed of *striated* fibre, the biceps for example, the fasciculus of fibres which is touched will immediately contract, and that one only; and the contracted fasciculus will soon relax, without communicating its movements to any other. The Heart, however, exhibits a different action, which is probably dependent upon the peculiar arrangement of its fibres, whereby the contraction of one set gives a mechanical stimulation to others; for the muscular substance of a large part of the organ is thrown into rapid and energetic contraction, by a stimulus applied at any one point; and this contraction is speedily followed by relaxation, which is again succeeded by a number of alternating contractions and relaxations. On the other hand, if we apply a similar irritation to a portion of *non-striated* fibre, as that of the Intestinal canal, the fasciculus which is stimulated will contract less suddenly, but ultimately to a greater amount; its relaxation will be less speedy; and, before it takes place, other fasciculi in the neighbourhood begin to contract; their contraction propagates itself to others; and so on. In this manner, successive contractions and relaxations may be produced through a considerable part of the canal, by a single prick with a scalpel; a sort of wave of contraction being transmitted in the direction of its length, and being followed by relaxation. Again, in the Muscular structure of the Bladder and Uterus (when the latter is fully developed), direct irritation excites immediate and powerful contractions, which extend beyond the fasciculus actually irritated, and produce a great degree of shortening; but they do not alternate, in the healthy state, with any rapid and decided elongation. And in the muscular tissue of the middle coat of the Arteries, the contraction takes place nearly in the same manner; a considerable degree of shortening being effected by the contraction of other fasciculi than those directly irritated, and this shortening not giving way speedily to relaxation; but a prolonged application of the stimulus is often necessary to produce the effect. —The effects of Electrical stimulation applied to the Muscles themselves, are very similar; but it is more difficult to confine the irritation to particular fasciculi of a voluntary muscle, and more easy to throw the whole mass into contraction at once by the transmission of a slight charge through it; and on certain forms of the non-striated fibre, the electric stimulus produces effects more decided than can be evoked in any other way. The difference in the endowments of the two kinds of tissue is particularly well seen, when they are subjected to the magneto-galvanic apparatus, which transmits a rapid succession of slight electric shocks; for these, in the striated muscles, immediately excite a state of rigid contraction, which lasts as long as the stimulus is transmitted, but ceases immediately that it is withdrawn; whilst in the non-striated fibres, the contraction is slowly excited, sometimes alternates with rest, and continues for a time after the electric discharges have ceased. Of this form of contractility, the muscular coats of the smaller arteries afford a particularly good example; for they may be made to contract by the magneto-galvanic apparatus, until they become quite impervious to blood; and yet the contraction neither takes place immediately upon the application of the stimulus, nor does it give place to relaxation directly that it is intermitted.*

* See Prof. Weber's researches upon this subject, in Wagner's "Handwörterbuch der Physiologie," Art. 'Muskelbewegung;' and "Müller's Archiv.," 1847, band ii.

317. On the other hand, when the stimuli which excite Muscular Contractility are applied to the *nerves* which supply any muscle composed of *striated* fibre (the Heart only excepted), they produce a simultaneous contraction in the whole muscle; the effect of the stimulus being at once exerted upon every part of it. The contraction speedily alternates with relaxation, unless the operation of the stimulus be continued,—as when an electric current is propagated without intermission along the nerve-trunks, —in which case the contraction lasts as long as the stimulus is continuously applied, but ceases as soon as it is withdrawn. But it has been shown by Volkmann,* that, if the electric stimulus be applied to the *central organs* from which the motor nerves arise, the muscular contraction continues for some time after its withdrawal. Further, he found that when the continuous electric current was passed through *incident* or excitor nerves, it produced alternating movements of contraction and relaxation, in the muscles which were thus called into play by reflex stimulation.—The ordinary actions of the *non-striated* fibre, on the other hand, are not easily excitable by stimuli applied to their nerves; indeed many Physiologists have denied the possibility of producing them through this channel. Abundant evidence that they *are* thus excitable, however, although the excitability speedily ceases after death, will be given hereafter (CHAP. XIV. SECT. 6). The results of Volkmann's recent electrical experiments upon the Heart and the Intestinal Canal are of much interest. He found that neither of these organs is thrown into fixed contraction, when the continuous electric current is applied to the Brain and Spinal Cord; whence he concludes that these organs are *not* the centres of *their* motor nerves. On the other hand, alternating contractions and relaxations were produced on applying the continuous current to the spinal cord, the par vagum, and the sympathetic nerves; whence it may be concluded that these parts contain afferent fibres, which excite motion through centres that can scarcely be any others than the ganglia of the Sympathetic system. When the Heart is removed from the body, and is left entire, it may be thrown into a state of fixed contraction, which lasts after the cessation of the current; whence it may be concluded, that it contains the centre of its own motor nerves.†—These experiments, however, by no means warrant the conclusion, that the ordinary actions of these muscular organs are *dependent* upon the agency of their nerves; a doctrine which is opposed by a variety of evidence.

318. The general fact, that Muscular contraction alternates with relaxation at no long intervals, is most evident in the rhythmical movements of the Heart,‡ and in the peristaltic action of the Intestinal canal;

* "Müller's Archiv.," 1844, No. 5, p. 407.

† Op. cit.; and Mr. Paget's 'Report' for 1845, in "Brit. and For. Med. Rev." July, 1846.

‡ Some curious rhythmical movements have been observed by M. Brown-Séquard, in the diaphragm, intercostals, and some of the muscles of locomotion, both after death, and after section of their nerves during life. These movements could not be in any way dependent upon reflex action, because they took place when the muscles were completely cut off from the nervous centres; sometimes to the number of from 5 to 20 in a minute, and for as long as a quarter of an hour after death; and occasionally recurring, in a living animal, for many months afterwards, especially when the respiration was impeded, and the circulation hurried.—The fact is of much importance, as showing that the rhythmical movements of the heart are by no means so exceptional (among the muscles composed of striated fibre) as they

since in these parts, the whole or a large proportion of the fibres seem to contract together, and then shortly relax. But it is probably no less true, as formerly stated (§ 303), of the individual fibres of those muscles, which are kept in a state of contraction by a stimulus transmitted through their nerves; since none of them appear, under ordinary circumstances at least, to remain in a contracted state for any length of time; a constant interchange of condition taking place among the fibres, some contracting whilst others are relaxing, and *vice versâ*. It is difficult to speak with confidence, however, in regard to the condition of the individual fibres of a muscle, that is thrown into a state of *continued spasmodic* contraction; such as that produced by the application of the electric current to the centre of its motor nerves (§ 317). A state of this kind is often of considerable duration. Thus the Author has known a case of Hysteric Trismus, in which the jaws remained closed with the greatest firmness during five days. Whether the individual fibres, in such instances, maintain a state of contraction without intermission, or whether the contraction of the entire muscle is kept up by a continual interchange of the fibres actually engaged, is a very curious subject for inquiry.

319. Muscles do not lose their Irritability immediately on the *general death* of the system, which must be considered as taking place, when the circulation ceases without a power of renewal; in cold-blooded animals it is retained much longer after this period, than in the higher Vertebrata in some of which it disappears within an hour. The muscles of young animals generally retain their irritability for a longer time than those of adults; on the other hand, those of Birds lose their irritability sooner than those of Mammalia. Hence, as a general rule, the duration of the irritability is inversely as the amount of respiration. From experiments on the bodies of executed criminals, who were previously in good health, Nysten ascertained that, in the Human subject, the irritability of the several muscular structures departs in the following time and order:— The left ventricle of the heart first; the intestinal canal at the end of 45 or 55 minutes; the urinary bladder nearly at the same time; the right ventricle after the lapse of an hour; the œsophagus at the expiration of an hour and a half; the iris a quarter of an hour later; the muscles of Animal life somewhat later; and lastly, the auricles of the heart, especially the right, which in one instance contracted under the influence of galvanism 16½ hours after death. It will be presently shown that the departure of the irritability is entirely dependent upon the cessation of the circulation; and that it may be prevented from disappearing, and may even be recalled after it has ceased to manifest itself, by transmitting a current of arterial blood through the muscles (§ 323).

320. Muscular Irritability is deadened by many substances, especially by those which have a narcotic or sedative action on the Nervous system. In carbonic acid gas, hydrogen, carbonic oxide, or sulphurous acid gas, muscles contract very feebly, or not at all, when stimulated; whilst in oxygen they retain their irritability longer than usual. Narcotic substances, such as a watery solution of opium, when applied directly to the muscles, have an immediate and powerful effect in diminishing or even destroying

are usually accounted; and also that there is a tendency to rhythmical movement in the muscles themselves, altogether independent of the excitement to action which they receive through the nervous system. ("Gazette Médicale," Dec. 22, 1849.)

their irritability; this effect is also produced, though in a less powerful degree, by injecting these substances into the blood. In the same manner, venous blood, charged with carbonic acid, and deficient in oxygen, has the effect of a poison upon muscles; diminishing their irritability, when it continues to circulate through them, to such a degree, that they sometimes lose it almost as soon as the circulation ceases, as is seen in those who have died from gradual and therefore prolonged Asphyxia. The unfavourable influence of venous blood is also shown in the Morbus Cœruleus; patients affected with which are incapable of any considerable muscular exertion.—Although most of the stimuli which occasion the contraction of muscles, when directly applied to their fibres, operate also when applied to their motor nerves, the same does not hold good in regard to those agents which diminish irritability. It is a fact of some importance, in relation to the disputed question of the connection of muscular irritability with the nervous system, that when, by the application of narcotic substances to the Nerves, *their* vital properties are destroyed, the irritability of the Muscle may remain for some time longer; showing that the latter must be independent of the former. This was proved some years since by Dr. W. H. Madden;* and Dr. Harless has more recently found that when the nervous system had been rendered, by the inhalation of ether, utterly incapable of conveying a galvanic stimulus, applied either to the nervous centres or to the nerve-trunks, the same stimulus, applied directly to the muscles, would immediately throw them into powerful contraction.† Various other experimenters have shown, that when the nerves supplying the muscles of a limb are divided, and the animals are allowed to live, excitants applied to the nerves beyond the point of division fail to produce muscular contractions, long before they cease to do so when applied to the muscles themselves. Hence it is obvious that the activity of the Nervous system is not essential to the manifestation of the characteristic endowment of the Muscular.

321. We find, however, that sudden and severe injuries of the Nervous centres have power to *impair*, directly and instantaneously, or even to *destroy*, the contractility of the whole Muscular system; so that death immediately results, and no irritability subsequently remains. It is in this manner that the *sudden* destruction of the Brain and Spinal Cord, especially of the latter, occasions the immediate cessation of the Heart's action; though they may be *gradually* removed, without any considerable effect upon it. Severe concussion has the same effect; hence the Syncope which *immediately* displays itself. It is sometimes an important question in Forensic Medicine, whether an individual, who has died from the effects of a blow upon the head, could have moved from the place where the blow was inflicted. If there be found, as is frequently the case, no sensible disorganization of the Brain, the death must be attributed to the concussion, and must have been in that case *immediate*. If, on the other hand, effusion of blood has taken place within the cranium, to any considerable extent, it is probable that the first effects of the blow were in some degree recovered-from, and that the circulation was re-established.—It is not essential, however, that the impression should be primarily made upon

* "Reports of the British Association," 1837, p. 103.
† "Müller's Archiv.," 1847, band ii.

the Cerebro-Spinal system. The well-known fact of sudden death not unfrequently resulting from a blow on the stomach, especially after a full meal, without any perceptible lesion of the viscera, clearly indicates that an impression upon the widely-spread cœliac plexus of Sympathetic nerves (which will be much more extensively communicated to them, when the stomach is full, than when it is empty), may cause the immediate cessation of the Heart's action, in the same manner as a violent injury of the Brain or Spinal Cord. In all these cases, *the whole vitality* of the system appears to be destroyed at once; for the processes which would otherwise succeed to the injury, and which, after other kinds of death less sudden in their character, produce evident changes in the part of the surface that has immediately received it, are here entirely prevented. An instance is on record, in which a criminal under sentence of death determined to anticipate the law by self-destruction. Having no other means of accomplishing his purpose, he stooped his head and ran violently against the wall of his cell; he immediately fell dead; and *no mark of contusion* showed itself on his forehead. The same absence of the usual results is to be noticed, in the case of blows on the stomach. Yet it is well known, that many of the ordinary vital processes will take place in the injured parts, after death of a more lingering nature; the vitality of the individual organs not being destroyed, immediately on the severance of the chain which binds together the different functions.—The influence of severe impressions on the Nervous system, in *diminishing*, where it does not altogether destroy, Muscular irritability, is well seen in the operation of severe injuries affecting vital organs, or extending over a large part of the surface, in depressing the Heart's action. This is a well-known result of severe burns, especially in children, whose nervous system is more susceptible of such impressions than that of the adult; also of the rupture of the alimentary canal, of the bladder or uterus; and of the shattering of one of the extremities, by violence affecting a large part of their substance. In all these cases, the sufferer is in the same condition with one who has received a severe blow on the head that does not quite stun him; the shock immediately diminishes the muscular contractility of the whole system; and its influence on the heart, which of course manifests itself most conspicuously, produces a degree of depression, which is frequently never recovered-from, and which at any rate renders necessary the employment of stimulants, for the purpose of counteracting this very dangerous effect.* Excessive mental Emotion, of a kind not in itself depressing, may occasion the sudden cessation of the heart's action, and a general loss of muscular irritability; and it is well known that muscular power is greatly diminished by emotions, which produce no other direct action.

322. There is no evidence that Muscular irritability can be *increased* by

* The large quantity of stimulus which can be borne even by children, suffering under severe burns, is very extraordinary. There can be no doubt that many lives have been saved by the judicious administration of them, to an amount, which would *à priori* have been judged in itself fatal; but that many more have been sacrificed to neglect, even on the part of those whose duty it is to watch the indications with the closest attention. The Author's observations lead him to believe, that Hospital Nurses very commonly make up their minds, that children, who have met with severe burns, *must* die; and that, unless closely watched, they neglect the means, of which Science and Experience alike dictate the free employment.

any cause operating through the Nervous system. It is quite true that under the agency of alcohol, nitrous oxide, or some of the other substances that rank as stimulants, individuals can perform actions requiring a degree of strength, which they cannot exert under ordinary circumstances. But it does not hence follow that the irritability is increased; since the energy of the movement is attributable solely to the increase of the nervous power by which it is excited, and to the unusual number of fibres called into simultaneous contraction. We have numerous examples of this kind, in cases in which the stimulus is purely mental; a state of general emotional excitement producing a temporary augmentation of the nerve-force transmitted to the muscular system, as is seen in violent fits of passion, and still more in Mania; or an extraordinary amount of nerve-force being determined to particular groups of muscles by the concentration of the attention upon them, in peculiar states of Abstraction, without any emotional excitement whatever (see CHAP. XIV., SECT. 7). It is well known that stimulating agents, which temporarily increase Muscular power, primarily excite the Nervous system; as is shown by the increased mental activity, which results from the moderate use of alcohol, nitrous oxide, opium, &c.; and it does not seem necessary, therefore, to go further, in search of an explanation of their effect on muscular action.

323. There can be no question that the condition most essential to the maintenance of Muscular contractility, is an adequate supply of *arterial blood*. It is well known that, when a ligature is applied to a large arterial trunk in the Human subject, there is not only a deficiency of sensibility in the surface, but also a partial or complete suspension of muscular power, until the collateral circulation is established. The same result has been constantly attained, in experiments upon the lower Animals; the contractility of the muscle being impaired or altogether extinguished, when the flow of blood into it was arrested; and being recovered again, when the supply of blood was restored.—The recent experiments of M. Brown-Séquard on this subject are still more satisfactory, as showing that the contractility of muscles may be *restored* by the transmission of aerated blood through them, after it has entirely ceased, and has even given place to cadaveric rigidity (§ 333). Thus he found that when he connected the aorta and vena cava of the body of a rabbit which had been some time dead, and in which the cadaveric rigidity had already manifested itself for between ten and twenty minutes, with the corresponding vessels of a living rabbit, so as to re-establish the circulation in the lower extremities, the rigidity disappeared in from six to ten minutes, and in two or three minutes afterwards the muscles contracted on being stimulated. He has subsequently made similar experiments upon the muscles of a decapitated criminal; the hand being selected as a convenient part for the purpose. It was not until nearly $12\frac{1}{2}$ hours after death, that all traces of irritability had left the muscles; and the injection was not commenced until 45 minutes after this, cadaveric rigidity having appeared in the interval. About half a pound of human blood, which had been defibrinated and freely exposed to the air so as to acquire the arterial tint, was then injected at intervals for about thirty-five minutes; ten minutes after the last injection, the greater number of the muscles were found to be irritable; and these remained so for two hours, after which the contractility gradually departed, and was succeeded by cada-

veric rigidity. The blood which had been injected in an arterialized condition, issued from the vessels quite dark; and as this occurred over and over again, the change of hue could not be attributed to anything else than the reaction between the blood and the tissues.—Similar experiments were made 27 hours after death, upon the muscles of the foot of the same criminal; but with an entirely negative result, save that the blood which was injected returned of a considerably darker hue.*

324. The influence of supply of Arterial blood upon the Muscles is twofold;—it affords the materials for the nutrition of the tissue;—and it furnishes (what is perhaps more *immediately* necessary) the supply of oxygen required for that *metamorphosis* of the tissue, which seems to be an essential condition of the generation of its contractile force. As this oxygen is taken-in through the lungs, and as the greater part of it is thrown off (when united with carbon into carbonic acid) by the same channel, we should expect to find a very close correspondence between the amount of muscular power developed in an animal, and the quantity of oxygen consumed in its respiration: and this is in reality the case. We find, for example, that in Birds and Insects, whose respiration is the highest, the muscular power is greater in proportion to their size, than in any other animals. In the Mammalia and certain Fishes that might be almost called warm-blooded, it is only in a degree inferior. But in the cold-blooded Reptiles, Fishes, and Mollusca, the muscular power is comparatively feeble; though even here we trace gradations, which accord well with the relative quantities of oxygen consumed. But in proportion to the feebleness of the power, do we usually find its duration greater (§ 319); so that it is not so immediately dependent upon the supply of oxygen, in cold-blooded, as in warm-blooded animals. Thus, it is found that Frogs are still capable of voluntary movement after the heart has been cut out, and can move limbs which are connected with the trunk by the nerves alone: and that this power is not altogether due to the blood which may remain in the capillary vessels, is shown by the experiment of Müller, who found the muscles still contractile, after he had expelled all the blood, by forcing a current of water into an artery, until it escaped from the divided veins.—It seems probable that the Muscles of Organic life are less immediately dependent upon a supply of arterialised blood, than are those of Animal life; for the Heart will continue to contract, when the blood in its vessels is entirely venous, and when the circulation in it has come to a stand. Still the dependence of its action upon a constant supply of arterial blood, is very close; and in all animals, however different the plans of their circulation, we find a provision for this supply, by a special arrangement of the coronary arteries. That the heart's action comes to an end much sooner, after the destruction of animal life by *pithing*, when the coronary arteries have been tied, than when they are left untouched, has been proved by the experiments of Mr. Erichsen.† In an animal that has been pithed, but whose heart has been left intact, artificial respiration will easily keep up its action for an hour, or an hour and a half. But when the coronary arteries were tied, a mean of six experiments gave a duration, for the ventricular action, of only 23½ minutes after the ligatures were applied, and 32½ minutes

* "Gazette Médicale," 1851, Nos. 24, 27.

† "Medical Gazette," July 8, 1842.

after the pithing; and in no instance was it prolonged more than 31 minutes after the application of the ligature, or 37 minutes after the pithing. On the other hand, when the aorta was tied, so that the coronary arteries were distended with blood, the circulation being carried on through them alone, the right ventricle continued to act up to the 82nd minute.

325. It has been maintained by many Physiologists, that the Irritability of Muscle is dependent upon the Nervous system; and the loss of that irritability, which usually follows division of the nerves of a voluntary muscle at no distant date, is continually cited as a proof of this dependence. Two views of this subject have been advanced, both of which demand some notice, on account of the eminence of the authorities by which they have been respectively sustained. The *first* of these is, that Muscular irritability is derived from some influence or energy communicated from the Brain or Spinal Cord, or that these organs supply some condition essential to its exercise; a doctrine of which, at the present time, Prof. Müller and Dr. M. Hall may be regarded as the principal supporters. The opinion that contractility cannot be an independent endowment of an organized structure, is at once negatived by the fact that, in Plants, we find tissues endowed with a high degree of contractility, and manifesting this property, without any possible intervention of a nervous system, on the application of stimuli to themselves. In the lower classes of animals, too, there is good reason to believe that contractility is more widely diffused through their tissues, than nervous agency can be; and we shall see that rhythmical contractions take place in the rudimentary heart, when as yet no nerves or ganglia have made their appearance. Again, the action of the heart may be kept up, in the highest Animals, by taking care that the current of the circulation be not interrupted, for a long time after the removal of the brain and spinal cord; it may even continue when completely separated from the body, which shows that the great centres of the ganglionic system cannot supply any influence necessary to it; and there are many instances, in which the Human fœtus has come to its full size, so that its heart must have regularly acted, without the existence of a brain or spinal cord. Further, the irritability of muscles of the first class continues for a long time after their nerves are divided; and may be called into action by stimuli directly applied to the parts themselves, or to their nerves below the section, so long as their nutrition is unimpaired.—The loss of the irritability of Muscles, within a few weeks after the section of their nerves, is clearly due to the alteration in their nutrition, consequent upon their disuse (§ 313). This has been proved to demonstration by the very ingenious experiments of Dr. J. Reid.* "The spinal nerves were cut across, as they lie in the lower part of the spinal canal, in four frogs; and both posterior extremities were thus insulated from their nervous connections with the spinal cord. The muscles of one of the paralysed limbs were daily exercised by a weak galvanic battery; while those of the other limb were allowed to remain quiescent. This was continued for two months; and at the end of that time, the muscles of the exercised

* "Edinburgh Monthly Journal of Medical Science," May, 1841; and "Physiological, Anatomical and Pathological Researches," p. 11.

limb retained their original size and firmness, and contracted vigourously, while those of the quiescent limb had shrunk to at least one-half of their former bulk, and presented a marked contrast with those of the exercised limb. The muscles of the quiescent limb still retained their contractility, even at the end of two months; but there can be little doubt that, from their imperfect nutrition, and the progressing changes in their physical structure, this would in no long time have disappeared, had circumstances permitted the prolongation of the experiment."* This experiment satisfactorily explains the fact observed by Dr. M. Hall, that in cases in which the cause of the paralysis is situated in the Brain, and in which the Spinal Cord and its nerves are unaffected, the irritability of the muscles of the paralysed part is not destroyed, even after a considerable lapse of time. For, if the capability of performing reflex actions still exist, on the part of the nervous system, it is manifest that the muscles will be occasionally excited to action through this channel; and that their nutrition and vital properties will thereby be preserved, as they were in Dr. Reid's experiments by the artificial excitement of galvanism.—Another equally satisfactory proof, that the loss of Irritability, which follows the severance of the connection between the Nervous centres and the Muscle, is not immediately due to the interruption of any influence communicated by the former, has been given by the experiments of Dr. J. Reid (loc. cit.); who found that if the irritability of Muscles be exhausted by means which have no tendency to impair their healthy nutrition, and the other conditions favour the normal performance of the nutrient processes, the irritability is restored, and remains for some time. His first experiments were on cold-blooded animals, and they would in themselves be sufficiently satisfactory; but their subsequent repetition in the Rabbit has established the fact beyond all doubt. "The sciatic nerve was divided in the Rabbit, and a portion of it removed. One wire from two galvanic batteries consisting of thirty pairs of plates, was applied over the course of the nerve; and the other wire was applied over the foot, which was kept moist, until the muscles had ceased to contract. Three days after this, a weaker battery was used, and the muscles of the limb had recovered their contractility, and contracted powerfully. The more powerful battery was used as before, until the muscles had ceased to respond to the excitement; and three days after this, they had again recovered their contractility." It seems scarcely possible to draw any other inference from these experiments, than that Irritability is a property inherent in Muscular tissue, and that the agency of the Nervous system upon it is merely to call it into active operation.

326. The second doctrine referred-to, as having been taught by some Physiologists, is, that Muscles, though not dependent on Nerves for their

* A fact of an exactly parallel character has fallen under the Author's observation, in a case of Hysteric Paraplegia, in which one leg was occasionally affected with severe cramps. The muscles of this leg suffered much less diminution of size and firmness, than those of the other; so that there was a difference of more than an inch in the circumference of the limbs. But since the paraplegia has been recovered from, voluntary power having been established in both limbs, and the muscles of both having been exercised in the same degree, they have regained their normal size and firmness, and there is no longer any perceptible difference between them.

peculiar vital power, are yet dependent upon them for the exercise of that power; all stimuli, which excite muscles to contraction, operating first on the nervous filaments which enter muscles, and through them on the muscular fibres.—The facts which have been already stated, in regard to the ordinary action of the Muscles of Organic life, furnish a sufficient answer to this hypothesis. It is with great difficulty that these can be made to display their irritability, by any stimuli applied to their nerves; whilst they manifest it strongly, when the stimulus is directly applied to themselves. Even in the Muscles of Animal life, individual fasciculi may be thrown into action in the same manner; although the entire mass cannot be put into combined operation, except by a stimulus simultaneously communicated to the whole, which the nerve affords the readiest means of effecting. Perhaps the most satisfactory disproof of it, however, is to be found in the observation of Mr. Bowman already cited (§ 302), that a single fibre, completely isolated from all its connections, may be seen with the microscope to pass into a state of contraction, under the influence of direct irritation. Further, it has been experimentally ascertained, that there are some chemical stimuli, which will produce the contraction of muscles when directly applied to them, but of which the influence cannot be transmitted through the nerves; this is especially the case with regard to acids.

327. When all these considerations are allowed their due weight, we can scarcely do otherwise than acquiesce fully in the doctrine of Haller, which involves no hypothesis, and which is perfectly conformable to the analogy of other departments of Physiology. He regarded every part of the body which is endowed with Irritability, as possessing that property in and by itself; but considered that the property is subjected to excitement and control from the Nervous System, the agency of which is one of the stimuli that can call it into operation.—It may be desirable briefly to recapitulate the facts, by which this doctrine is supportod. 1. The existence in Vegetables of irritable tissues, which are excited to contraction by stimuli directly applied to themselves, and which can be in no way dependent upon, or influenced by, a Nervous system. 2. The existence in Animals of a form of Muscular tissue, which is especially connected with the maintenance of the Organic functions, and which is much more readily excited to action by direct stimulation, than it is by Nervous agency. 3. The fact that, by the agency of these, the organic functions may go on (so long as their other requisite conditions are supplied) after the removal of the nervous centres (of the Cerebro-spinal system at least) and when these were never present; rendering it next to certain, that their ordinary operations are not dependent upon any stimuli received through the nerves, but upon those directly applied to themselves. 4. The persistence of irritability in Muscles, for some time after the Nerves have ceased to be able to convey to them the effects of stimuli; this is constantly seen in regard to the Sympathetic system of nerves, and the muscles of Organic life upon which they operate; and it is shown, by the agency of narcotics, to be true also with respect to the Cerebro-Spinal system and the muscles of Animal life. 5. The persistence of irritability in the muscles, after their complete isolation from the nervous centres, so long as their nutrition is unimpaired; and the effects of frequent exercise, in preventing the impairment of the nutrition and

the loss of irritability. 6. The recovery of the irritability of muscles, when isolated from the nervous centres, after it has been exhausted by repeated stimulation; this also depends upon the healthy performance of the nutritive actions. 7. The contraction of muscular fibre under the microscope, when completely isolated from all other tissues.—In the words of Dr. Alison, then, "the only ascertained final cause of all endowments bestowed on Nerves in relation to Muscles, in the living body, appears to be, not to make Muscles irritable, but to subject their irritability, in different ways, to the dominion of the acts and feelings of the Mind,"—to its volitions, emotions, and instinctive determinations.

328. Whilst the Irritability of Muscles is gradually departing after death, it not unfrequently shows itself under a peculiar form; for instead of producing sudden contractions, speedily followed by relaxation, the application of stimuli then occasions slow and somewhat prolonged contractions, the relaxation after which is tardy. This form of contraction is seldom seen in adult Mammalia, except (as will be presently shown) when death has taken place from certain diseases that have a special influence on the blood and muscular system; but it is stated by M. Brown-Séquard * to present itself more constantly in young animals, and to be (so to speak) an exaggeration of the ordinary *modus operandi* of their muscles, which, during life, are much more slowly thrown into contraction by mechanical stimuli, than they are in adults.—The most remarkable manifestations of it yet observed, however, have been witnessed after death from Cholera and Yellow fever; for in these cases, the muscular contractions, though capable of being excited by mechanical stimulation applied to the muscles themselves, are frequently spontaneous, and sometimes give rise to movements strongly resembling the ordinary actions of the living state. Thus in one case, about ten minutes after the cessation of the respiration and circulation, Mr. N. B. Ward saw the eyes open, and move slowly in a downward direction; this was followed, a minute or two subsequently, by the movement of the right arm (previously lying by the side) across the chest; there was also a slight movement of the right leg; and these movements of the limbs (those of the eyes occurring only once) were repeated to a greater or less degree four or five times, and fully half an hour elapsed before they entirely ceased. In a case observed by Mr. Helps, the subject of which was a man of remarkable muscular development, the fingers continually twitched and trembled after the respiration had ceased, and the fibres of the muscles were in state of rhythmical motion, so that when the fingers were pressed on the belly of the biceps, a sensation as of the pulsation of an artery was plainly felt; the muscles of the arm acted forcibly on even slight irritation, the fore-arm being powerfully flexed when the biceps was struck with the side of the hand, and the fist being doubled or the hand extended, according as the flexors or extensors on the fore-arm were irritated in the same manner. Various other muscles were acted-on, with the same results; and it was noticed in this case, that the longer the muscles were allowed to remain without irritation, the more powerfully did they contract when excited.† — In regard to the occurrence of this

* "Gazette Médicale," Dec. 22, 1849.

† See Mr. Fredk. Barlow's 'Observations on the Muscular Contractions which occasionally occur after Death from Cholera,' in the "Medical Gazette" for Nov. 9, 1849, and Feb. 1, 1850.

phenomenon after death from Yellow Fever, several interesting observations have been recorded by Dr. Bennet Dowler of New Orleans.* In one case, the subject of which was an Irishman aged twenty-eight, the following series of movements took place spontaneously, not long after the cessation of the respiration: first, the left hand was carried by a regular motion to the throat, and then to the crown of the head; the right arm followed the same route on the right side; the left arm was then carried back to the throat, and thence to the breast, reversing all its original motions; and finally the right arm and hand did exactly the same. In another case, that of a Kentuckian aged twenty-five, the movements were only exhibited on mechanical stimulation: when the arm was extended to an angle of 45° from the trunk, and was struck with the hand or with the flat side of a hatchet, the hand was carried inwards to the epigastrium; but when the arm was extended upon the floor, so as to form a right angle with the body, the hand slapped the mouth and nose. In like manner, when the leg was hanging down, if the flexors of the hamstring muscles were struck, the heel was drawn up against the buttock. The contractility began to decline in the third hour; and by the fourth, all motions of the limbs ceased, though the pectoral muscles assumed the ridgy or lumpy form when percussed. Five hours after death, the contractility had ceased, and rigidity had supervened.—Many circumstances indicate that these movements were due to the inherent contractility of the muscles, and were not in any degree dependent upon the operation of the nervous system; and Dr. Dowler proved experimentally, by completely separating limbs which exhibited these movements, from the trunk of the body, that the influence of the nervous centres was not in any degree essential to their production.†—A phenomenon of a similar order has been observed by Dr. Stokes,‡ even during the life of the subject. In various cases of phthisis and of other exhausting diseases, a sharp tap with the fingers on any muscular part is instantly followed by a contraction of the part which receives the irritation, evidenced by the rise of a defined firm swelling, which is often so prominent as to throw a shadow along the skin, and which endures for several seconds before it gradually subsides. The complete limitation of this contraction to the part struck, is sufficient evidence that it must be attributed to direct stimulation of the muscle itself, and not to a 'reflex' action of the nervous system.

329. A curious question has been lately raised, the decision on which is of some importance in our determination of the nature of the force, by which the contraction of muscles is occasioned. This is,—whether the power of a muscle is greater or less at different degrees of contraction, the same stimulus being applied. This seems to have been determined by the ingeniously-devised experiments of Schwann.§ He contrived an appa-

* "Experimental Researches on the Post-Mortem Contractility of the Muscles," reprinted from the "New York Journal of Medicine," 1846.

† It is remarkable that, in the case of both these diseases, the temperature of the corpse usually rises considerably after death, so as to approach its usual standard when the body has been previously cooled down much below it, and to rise considerably higher when there has been no previous depression (CHAP. XIII.). Moreover, the cadaveric rigidity is usually long in coming on; being sometimes postponed for many days after death from Cholera.

‡ "On Diseases of the Chest," p. 397.

§ Müller's "Elements of Physiology," translated by Baly, p. 903.

ratus, which should accurately measure the length of the muscle, and, at the same time, the weight which it would balance by its contraction. Having caused the muscle of a Frog to shorten to its extreme point, by the stimulus of galvanism applied to the nerve, so that no further stimulation could lift a weight placed in the opposite scale, he allowed the muscle to relax until it was extended to a certain point, and then ascertained the weight which would balance its power. The same was several times repeated, as in the following manner:—The length of the muscle in its extreme state of contraction, at which no additional force could be exerted by it, being represented by 14, it was found that, when it had been extended to 17, it would balance a weight of 60; when its length increased to 19·6, it would balance a weight of 120; and at 22·5, it would balance 180. In another experiment, the muscle at 13·5, balanced 0; at 18·8, it balanced 100; and at 23·4, it balanced 200. Hence it appears that a uniform increase of force corresponds with a nearly uniform increase in the length of the muscle; or, in other words, that when the muscle is nearly at its full length, its contractile power is the greatest. In later experiments upon the same muscle, this uniform ratio seemed to be departed from; but, by comparing the results in a considerable number of instances, it was constantly found that, in those experiments which were performed the soonest after the preparation of the frog, and in which, therefore, the normal conditions of the system were the least disturbed, the ratio was very closely maintained. It has been ascertained by Valentin, on repeating these experiments, that, by repeated equal irritations, the strength of the muscles in decapitated frogs decreases in a regular and corresponding ratio; losing the same amount in each successive period of time. He also found that, when all the Irritability has ceased, the muscles *tear* with a far less weight, than they were previously able, when galvanized, to *draw*.*

330. It appears from the researches of MM. Becquerel and Breschet,† that Muscular contraction is attended with a disengagement of *Heat*. By careful experiments, conducted with the aid of the 'thermo-multiplier,' they ascertained that the temperature of a large muscle, such as the Biceps, uses as much as 1° (Fahr.) when it is thrown into vigorous contraction; and that repeated movements of any one kind (as in the act of sawing) increase the temperature of the muscles which execute them as much as 2°. This development of Heat may be attributed with probability to the chemical changes which take place in the Muscular substance, when it is in a state of functional activity (§ 311); or it may be occasioned

* It has been inferred by Müller, from Schwann's experiments, that the power which causes the contraction of a Muscle, must be very different in its character from any of the forces of attraction known to us; since these all increase in energy as the attracted parts approach each other, in the inverse ratio of the square of the distance; so that the power of a Muscle, if operated on by any of these, ought to increase, instead of regularly diminishing, with its degree of contraction. But it is to be remembered that, as the observations of Mr. Bowman have clearly shown, there must be a considerable displacement of the constituents of every fibre during contraction (§ 302); so that it is easy to understand that, the greater the contraction, the more difficult must any further contraction become. If, between a magnet and a piece of iron attracted by it, there were interposed a spongy elastic tissue, the iron would cease to approach the magnet at a point, at which the attraction of the magnet would be balanced by the force needed to compress still further the intermediate substance.

† "Archives du Muséum," tom. ii. p. 402.

by the friction of its parts, one upon another; or we may consider that, like Motion, it is a direct result of the metamorphosis of the force which was previously operative in the vital actions of Development and Nutrition.*—It has been many times affirmed, but as frequently denied, that *Electricity* is developed during Muscular contraction. The recent researches of Prof. Matteucci upon the cause of the phenomenon which he terms 'induced contraction,' have led him to an affirmative conclusion upon this important point. This 'induced contraction' takes place in the muscles of a prepared 'galvanoscopic frog,'† when its nerve is laid upon the muscles of another frog, which are thrown into contraction by electrical, mechanical, or any other stimulation of its nerves. It is requisite that the nerve of the 'galvanoscopic' frog should touch two different points of the contracting muscle or limb of the entire frog; just as it is necessary that two different points of the electrical apparatus of the Torpedo or Gymnotus should be touched at once, in order to obtain manifestations of electricity. Prof. Matteucci has not succeeded in obtaining proof of electric disturbance in contracting muscles, by any other means than the use of the 'galvanoscopic' frog; the most delicate galvanometer not affording unexceptionable indications of it.‡ But he considers that the phenomena of 'induced contraction,' which he has experimentally studied under a great variety of conditions, are sufficient to "demonstrate the production of an electrical *disequilibrium* in the act of muscular contraction."§—This production of Electric disturbance in muscular contraction may be attributed to either or all of the causes which have been suggested for the development of heat; but that it is specially connected with the chemical changes which then take place, seems probable from the fact that a contraction in the muscles of the galvanoscopic frog is seen, when its nerve is simply introduced into an incision made in the muscle of a living or a recently-killed animal, in

* It is suggested by Nasse, that this elevation of the temperature of Muscles in action is due to the increased afflux of arterial blood, which, according to him, is of higher temperature than venous. But this position is by no means satisfactorily established.

† The 'galvanoscopic frog,' which has been continually employed by Prof. Matteucci to test minute electrical disturbances which are not appreciable by a galvanometer, is simply the leg of a recently-killed frog, with the crural nerve, dissected out of the body, remaining in connection with it: the leg being enclosed in a glass tube covered with an insulating varnish, and the nerve being allowed to hang freely from its open end, when two points of the nerve are brought into contact with any two substances in different electrical states, the muscles which it supplies are thrown into contraction.

‡ On this account, Prof. Matteucci distrusts the results which have been obtained by M. Du Bois Reymond; who affirms that when the corresponding fingers of the two hands are immersed in two vessels filled with salt water, into which are plunged two slips of platina connected with the wires of a very delicate galvanometer, a very sensible deflection of the needle, indicating a current from the hand to the shoulder, is produced by putting the muscles of one arm in contraction against each other; this deflection being considerably increased by alternately contracting the muscles, first of one arm, and then of the other, in time with the oscillations of the needle. Nevertheless Prof. Matteucci (whose authority on this subject stands most deservedly high), after pointing out various sources of error in the use of the galvanometer, states that he has tried a great number of experiments after M. Du Bois Reymond's method, increasing the number of elements which contract at the same time (as by operating on a circle of thirty or forty individuals, who all contracted the same arm at once) without ever succeeding in obtaining an evident and constant development of electricity by muscular contraction. (See "Phil. Trans.," 1850, p. 646).

§ "Philosophical Transactions," 1850, p. 649. See also Prof. Matteucci's previous researches on 'induced contraction,' in the "Phil. Trans." for 1845 and 1847.

such a manner that the extremity is applied to the deepest part of the wound, and another portion to its lips or to the surface of the muscle. As this contraction takes place when the muscle is completely passive, it is obvious that the source of the electric current which determines it must lie in the molecular changes taking place in the course of the nutrition of the muscle; and the explanation of its constant direction from the interior to the exterior of the muscle seems to lie in the difference in the rate of these changes, which will go on more energetically in its interior than they will do nearer its surface, where the proper muscular fibres are mingled with a larger proportion of areolar and tendinous substance.*— Muscular contraction also gives rise to the production of *Sound*, as was first noticed by Dr. Wollaston.† When the ear is applied to a muscle in action, a sound is heard resembling the distant rumbling of carriage-wheels, or an exceedingly rapid and faint tremulous vibration, which, when well marked, has an almost metallic tone. This sound may be readily made audible in the manner suggested by Dr. Wollaston; namely, by placing the tip of the little finger in the ear, and then making some muscles contract (as those of the ball of the thumb), whose sound may be conducted to the ear through the substance of the hand and finger. The continuity of this sound through the whole period during which contraction is maintained, is an important confirmation of the view which is based on other foundations, that there is a continual alternation of contractions and relaxations among the individual fibres of any Muscle which is putting forth its contractile power, as a whole, for any length of time (§ 303). The sound may be readily conceived to depend upon the friction of the elements of the muscle, one upon another; which must thus be perpetually taking place, so long as it continues in a state of activity. There can be little question that the *first* sound of the Heart, which accompanies the ventricular systole, is partly attributable to muscular contraction.

331. *Of Muscular Tonicity.*—We have now to consider the other form of Contractility, which produces a *constant* tendency to contraction (varying, however, as to its degree) in the Muscular fibre; but which is so far different from simple Elasticity, that it abates after death, before decomposition has taken place. This Tonicity is to be distinguished from the Muscular 'tension,' which is the result of the 'reflex' operation of the nervous centres (CHAP. XIV., SECT. 2); being manifested as well when the muscle is altogether removed from nervous influence, as when subjected to it; and being, like Irritability, an inherent property of the tissue itself, the presence of which is characteristic of its living state. It manifests itself in the retraction which takes place in the ends of a living muscle, when it is divided (as is seen in amputation); this retraction being permanent, and greater than that of a dead muscle. But its effects are much more remarkable in the non-striated, than in the striated form of Muscular fibre; and are particularly evident in the contractile coat of the Arteries, causing the almost entire obliteration of their tubes, when they are no longer distended with blood. The disposition to tonic contraction is increased by any considerable change of temperature; the power of

* See Prof. Matteucci's "Lectures on the Physical Phenomena of Living Beings," Lects. ix. and x.

† "Philosophical Transactions," 1811.

Heat is well seen in the following experiments by John Hunter:—"As soon as the skin could be removed from a sheep that was newly killed, a square piece of muscle was cut off, which was afterwards divided into three pieces, in the direction of the fibres; each piece was put into a bason of water, the water in each bason being of different temperatures, viz., one about 125°, about 27° warmer than the animal; another 98°, the heat of the animal; and the third 55°, about 43° colder than the animal. The muscle in the water heated to 125° contracted directly, so as to be half an inch shorter than the other two, and was hard and stiff. The muscle in the water heated to 98° after six minutes began to contract and grow stiff; and at the end of twenty minutes it was nearly, though not quite, as short and hard as the above. The muscle in the water heated to 55°, after fifteen minutes, began to shorten and grow hard; after twenty minutes it was nearly as short and as hard as that in the water heated to 98°. At the end of twenty-four hours, they were all found to be of the same length and stiffness."* The agency of Heat in producing this contraction is also remarkably shown in the fact, that if a Frog be immersed in water of the temperature of 110°, the muscles of its body and limbs will be thrown into a state of permanent and rigid contraction.—But it would seem that these effects are chiefly, if not entirely, exerted upon the striated form of Muscular fibre; and that the tonicity of the non-striated fibre is called into play by Cold, rather than by heat. For if a Tadpole or Frog be immersed in water, the temperature of which is *gradually* raised, until this state of contraction comes on, the Heart will be found to continue pulsating for many hours afterwards, not being affected by the heat. On the other hand, if an artery in a living warm-blooded animal be exposed to cold air for some time, the lowering of its temperature occasions its contraction to such an extent, that its cavity becomes almost obliterated. The influence of warmth in diminishing, and of cold in increasing, the tonic contraction of the Arterial system, will be adverted to hereafter (CHAP. IX., SECT. 3).

332. The distinctness of the Tonicity of Muscles from their Irritability, is further shown by the fact, that the former commonly survives the latter; and that it is not destroyed by treatment which occasions the complete departure of the Irritability. The first of these statements finds its proof in the phenomena of 'cadaveric rigidity' to be presently adverted to. Of the latter, the following remarkable experiment by John Hunter is an ample demonstration:—"From a straight muscle in a bullock's neck, a portion, three inches in length, was taken out immediately after the animal had been knocked down, and was exposed between two pieces of lead, to a cold below 0°, for fourteen minutes; at the end of this time it was found to be frozen exceedingly hard, was become white, and was now only two inches long: it was thawed gradually, and in about six hours after thawing it contracted so as only to measure one inch in length; but irritation did not produce any sensible motion in the fibres. Here, then, were the juices of muscles frozen, so as to prevent all power of contraction in their fibres, without destroying their life; for when thawed they showed the same life which they had before: this is exactly similar to the freezing of

* 'General Principles of the Blood,' in "Hunter's Works" (Palmer's Edition), vol. iii. p. 110.

blood too fast for its coagulation, which, when thawed, does afterwards coagulate, as it depends in each on the life of the part not being destroyed."*

333. The *Rigor Mortis*, or cadaveric stiffening of the muscles, is probably to be regarded as the final manifestation of this property; occurring after all the Irritability of the muscles has departed, but before any putrefactive change has commenced. The supervention of the rigidity is not usually prolonged much beyond seven hours; but twenty or even thirty hours *may* elapse, before it shows itself. Its general duration is from twenty-four to thirty-six hours; but it may pass off much more rapidly; or it may be prolonged through several days. It first affects the neck and lower jaw, and seems gradually to travel downwards; but, according to some observers, the lower extremities are stiffened before the upper. In its departure, which is immediately followed by decomposition, the same order is observed. It affects all the muscles nearly alike; but the flexors are usually more contracted than the extensors, so that the fingers are somewhat flexed on the palm, and the fore-arm on the arm; and the lower jaw, if previously drooping, is commonly drawn firmly against the upper. It is remarkable that it is equally intense in muscles which have been paralysed by Hemiplegia, provided that no considerable change has taken place in their nutrition. When very strong, it renders the muscles prominent, as in voluntary contraction.—An attempt has been made to connect it with the lowering of the Temperature of the dead body; but with this it does not seem to have any relation, since it has frequently been observed to commence long before the heat has entirely departed from the body, and appears first upon the trunk, which is the region last deserted by warmth. Another attempt has been made to show a correspondence between the Rigor Mortis and the Coagulation of the Blood in the vessels; and there is certainly evidence enough to make it appear, that some analogy exists between these two actions, though they are far from being identical. After those forms of death, in which the blood does not coagulate, or coagulates feebly, the rigidity commonly manifests itself least; but this is by no means an invariable rule. It seems probable that, as the coagulation of the blood is the last act of its vitality (§ 29), so the stiffening of the muscles is the expiring effort of theirs.†

* 'General Principles of the Blood,' in "Hunter's Works" (Palmer's Edition), vol. iii. p. 109.

† It is necessary to bear in mind, when the phenomena of Cadaveric Rigidity are brought into question in juridical investigations, that a state at first sight corresponding to it may supervene *immediately* upon death, from some peculiar condition of the nervous and muscular systems at the moment. This has been observed in some cases of Asphyxia; but chiefly when death has resulted from apoplexy following chronic *ramollissement* of the brain or spinal cord. This contraction, which is obviously of a tetanic character, ceases after a few hours; and is then succeeded by a state of flexibility, after which the ordinary rigidity supervenes.—The following case illustrates the nature of the inquiries, to which this condition may give rise. The body of a man was found in a ditch, with the trunk and limbs in such a relative position, as could only be maintained by the stiffness of the articulations. This stiffness must have come on at the very moment when the body took that position; unless it could be imagined, that the body had been supported by the alleged murderers, until the joints were locked by cadaveric stiffness. A post-mortem examination showed that there was no necessity for this supposition—obviously a very improbable one in itself,—by affording sufficient evidence that apoplexy, resulting from chronic disease, was the cause of death. A case

334. This phenomenon is rarely absent; though it may be so slight, and may last for so short a time, as to escape observation. The period which elapses before its commencement, is as variable as its duration; and both appear to be in some degree dependent upon the vital condition of the body at the time of death. When the fatal termination has supervened on slow and wasting disease, occasioning great general depression of the vital powers, the rigidity usually developes itself very early, and lasts for a short time. And the same is the case, when the muscular Irritability has been exhausted previously or subsequently to death, by repeated and powerful stimulation. Thus M. Brown-Séquard,* having been desirous of ascertaining the influence of electricity upon the development of the rigidity, subjected the bodies of four rabbits of the same age and vigour, which had been killed by the removal of the heart, to electro-magnetic currents of different intensities; a similar animal, killed in the same manner, being reserved for comparison. The following were the results:—

| | | | | | |
|---|---|---|---|---|---|
| I. | Not electrized. | Rigidity came on in 10 | hours, | and lasted 192 | hours. |
| II. | Feebly electrized . | . 7 | ,, | ,, 144 | ,, |
| III. | Somewhat more electrized | . 2 | ,, | ,, 72 | ,, |
| IV. | Still more strongly electrized | . 1 | ,, | ,, 20 | ,, |
| V. | Submitted to a powerful current | . 7 | min. | ,, 25 | min. |

Thus it appears that, the more powerful the electric current, the earlier does the rigidity appear, and the shorter is its duration; and hence we can readily understand that, when an animal is killed by a stroke of lightning, the rigidity may supervene so rapidly, and may depart again so early, as to pass completely unnoticed; and we may even admit the possibility of the vitality being so completely and immediately destroyed, that the rigidity shall not occur at all. M. Brown-Séquard has further ascertained,† that the application of the electric current previously to death speedily induces the rigidity, which on its departure is followed by rapid putrefaction. Thus, one of the posterior members of a rabbit was subjected for half an hour to a powerful electro-magnetic current, and the animal was soon afterwards killed; in about two hours and a half, cadaveric rigidity had already commenced in the electrized limb, while the other member was still supple; about two hours afterwards, the rigidity had already begun to diminish in the electrized limb, whilst it had scarcely commenced in the other; at the end of two days, the electrized limb was already in incipient decomposition, whilst the other was still rigid:

occurred a few years since in Scotland, in which the same plea was raised. The body was found in a position, in which it could have only been retained by rigidity of the joints; and it was pleaded on the part of the prisoner, that death had been natural, and had resulted from fracture of the *processus dentatus*, causing sudden pressure upon the spinal cord, whence the spasmodic rigidity would naturally result. Proof was deficient, however, as to the existence of this lesion before death; and the position of the body rather resembled that into which it might have been forced during the rigidity, than that in which it would probably have been at the moment of death. There were also marks of violence, and many other suspicious circumstances; but the prisoner was acquitted, chiefly from want of evidence against him. What seemed to indicate that the rigidity was of the ordinary cadaveric nature, was, that there was no evidence of the body having become flexible and again stiffened; as it would probably have done, had the rigidity been of the spasmodic character. (See "Annales d'Hygiène," tom. vii.; and "Watson on Homicide," pp. 70, 266.)

* "Gazette Médicale," 1849, No. 45. † Op. cit., Dec. 22, 1849.

eight days after death, the electrized limb was far advanced in putrefaction, but the other limb was still rigid; and its rigidity continued until the ninth day, putrefaction not supervening until the twelfth.—If the irritability be exhausted previously to death, by other causes, the effect is the same. Thus it was affirmed by Hunter, that animals hunted to death do not stiffen; and although subsequent inquiry has shown that this statement is not precisely correct, yet the rigidity comes on very early in such cases (a few minutes after death), and lasts but for a short time.* So, it has been remarked by M. Brown-Séquard, that when animals die from the effects of poisons which produce convulsions, the rigidity appears earlier and departs sooner, in proportion to the violence of the previous convulsive action. The same is the case, moreover, in some diseases which powerfully affect the general vital energy, even though they may not have been of long duration; thus, after death from Typhus, the limbs have been sometimes known to stiffen within fifteen or twenty minutes. The same is observed in infants and in old people. On the other hand, where the general energy has been retained up to a short period before death, the rigidity is much later in coming on, and lasts longer; this happens, for example, in many cases of Asphyxia and Poisoning, in which it has been said not to occur at all.

335. As the property of Tonicity manifests itself most decidedly in the non-striated muscles in the living body, so do we find this post-mortem contraction most remarkable in them. As soon as the muscular walls of the several cavities lose their irritability, they begin to contract firmly upon their contents, and thus become stiff and firm, though they were previously flaccid. In this manner, the ventricles of the Heart, which are the first parts to lose their irritability, become rigid and contracted within an hour or two after death; and usually remain in that state for ten or twelve hours, sometimes for twenty-four or thirty-six, then again becoming relaxed and flaccid. This rigid contracted state of the heart, in which the walls are thickened and the cavities diminished, was formerly supposed to be a result of disease, and was termed *concentric hypertrophy*; but it is now known, from the inquiries of Mr. Paget, to be the natural condition of the organ, at the period when the 'rigor mortis' occurs in it.—The contraction of the Arterial tubes is so great, as to produce for the time a great diminution in their calibre; and this doubtless contributes to the passage of the blood from the arterial into the venous system, which almost invariably takes place within a few hours after death. The arteries then enlarge again, and become quite flaccid, their tubes being emptied of their previous contents; and it was from this circumstance, that the ancient Physiologists were led to imagine, that the arteries are not destined to carry blood, but air.—So it has been shown by Prof. Valentin,† that if a graduated tube be connected with a portion of Intestine taken from a recently-killed animal, filled with water, and tied at the opposite end, the water will rise in a few hours to a considerable height in the tube, owing to the contraction of the intestinal walls. The post-mortem contraction of the parturient uterus, to such an extent as to expel the fœtus of which

* See Mr. Gulliver 'On the state of the Blood and Muscles in Animals killed by Hunting and Fighting,' in "Edinb. Med. and Surg. Journ.," Oct., 1848.

† "Lehrbuch der Physiologie," band ii. p. 36.

the patient had died undelivered, is a phenomenon which has been several times recorded; and Dr. Robert Lee has witnessed one remarkable case, in which, the patient having died suddenly from the rupture of the uterus and escape of the fœtus into the abdominal cavity, the uterus was found, when an examination was made twenty-four hours after death, to be completely inverted.*

### 7. *Of the Nervous Tissue.*

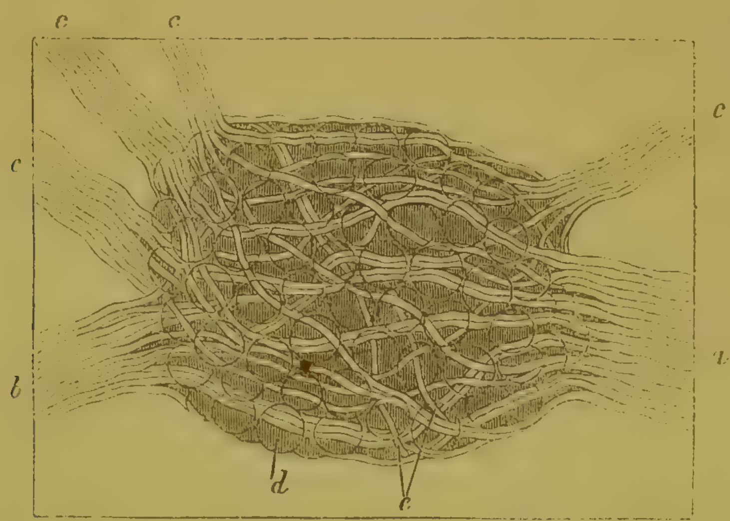
336. We have, lastly, to consider the structure, composition, mode of growth and regeneration, and special vital actions, of the *Nervous* tissue; the one whose existence is most distinctive of the Animal fabric, and which serves as the instrument of the operations that are most peculiar to it. Wherever a distinct Nervous System can be made out (which has not yet been found possible in the lowest of those beings, which, from their general structure and habits of life, cannot but be ranked in the Animal Kingdom), it is found to consist of two very different forms of structure; the presence of both of which, therefore, is essential to our idea of it as a whole. We observe, in the first place, that it is formed of *trunks*, which are distributed to different parts of the body, and especially to the muscles and to the sensory surfaces; and of *ganglia*, or masses with which the central terminations of those trunks come into connection. It is easily established by experiment, that the trunks themselves have no power of *originating* changes; and that they only serve to *conduct* or *convey* the influence of operations, which take place at their central or their peripheral extremities. For if a trunk be divided in any part of its course, all the organs to which the portion thus cut off from the ganglion is distributed, are completely paralysed; that is, no impression made upon them is felt as a sensation, or produces any respondent movement; and no motion can be excited in them by any act of the mind. Or, if the substance of the ganglion be destroyed, all the parts which are exclusively supplied by nervous trunks proceeding from it, are in like manner paralyzed.—But if, when a trunk is divided, the portion still connected with the ganglion be pinched or otherwise irritated, sensations are felt, which are referred to the points supplied by the separated portion of the trunk; which shows that the part remaining in connection with the ganglion is still capable of conveying impressions, and that the ganglion itself receives these impressions, and makes them felt as sensations. On the other hand, if the separated portion of the trunk be irritated, motions are excited in the muscles which it supplies; showing that it is still capable of conveying the motor influence, though cut off from the usual source of that influence.

337. In the ordinary Nerve-trunks, we find only one form of Nervous tissue; that which may be designated as the *fibrous* or *tubular*. In the Ganglia, we find, in addition to this, a substance made up of peculiar cells or vesicles; which may be distinguished as the *vesicular* nervous matter. In fact, the character of a Ganglionic centre (which is frequently not

* See Dr. Tyler Smith's "Parturition, and the Principles and Practice of Obstetrics," p. 39.—The Author believes that Dr. T. Smith was the first to attribute this set of phenomena to the cadaveric rigidity of the uterus.

otherwise clearly distinguished as such) is derived from the presence of this vesicular substance (Fig. 84).

FIG. 84.

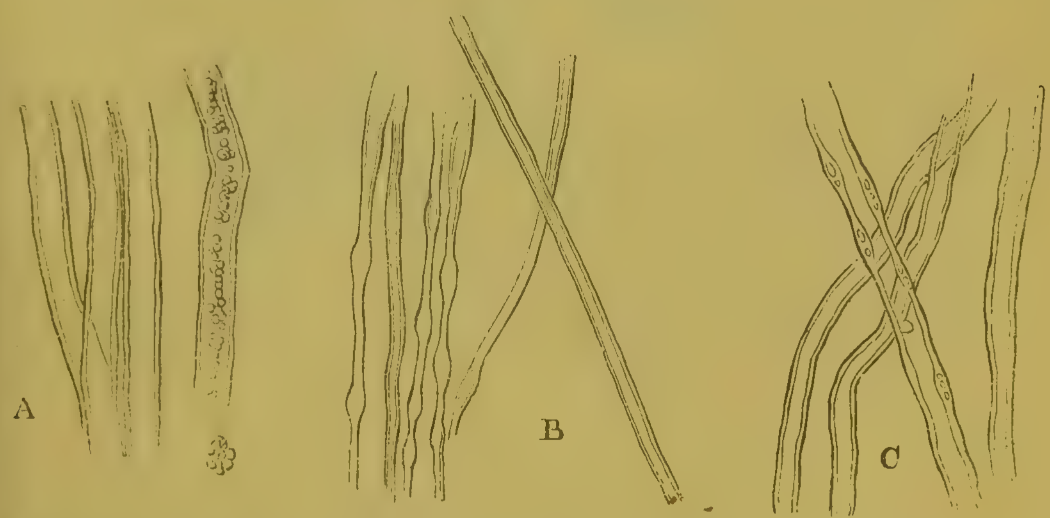



Dorsal *Ganglion of Sympathetic nerve* of Mouse:—*a*, *b*, cords of connection with adjacent sympathetic ganglia; *c*, *c*, *c*, *c*, branches to the viscera and spinal nerves; *d*, ganglionic globules or cells; *e*, nervous fibres traversing the ganglion.

338. The ultimate *Nerve-Fibre*, in its most complete form,—such as is presented to us in the ordinary cranio-spinal nerves,—is distinctly tubular; being composed of an external cylindrical membranous sheath, within which the peculiar nervous matter is contained. This membranous tube, like the Myolemma of muscular fibre, is extremely delicate and transparent; and is nearly or quite homogeneous. It is not penetrated by blood-vessels; nor is it ever seen to branch or anastomose with others; so that there is reason to regard it as forming one continuous sheath, which isolates the contained matter from the surrounding tissue, along the whole course of the nerve-trunk, from its central to its peripheral extremity. When the nerve-fibres are examined in a very fresh state, their contents appear pellucid and homogeneous, and of a fluid consistence; so that each tube or fibre looks like a cylinder of clear glass, with simple, well-defined, dark edges. But a kind of coagulation soon takes place in the contained substance, making it easily distinguishable from the tube itself; for the latter is then marked by a *double* line, as shown in Fig. 85, A. The substance which is in immediate contact with the inner wall of the nerve-tube, is more opaque than that which occupies its centre, and of a different refractive power; and thus it forms a hollow cylinder, which surrounds the latter, and which is known under the name of the 'white substance of Schwann.' The centre or axis of the tube is occupied by a substance that preserves its transparency; and this is the 'axis-cylinder' of Rosenthal and Purkinje, the 'primitive band' of Remak. Much discussion has taken place respecting the condition under which this central substance exists in the living nerve-fibre; some microscopists considering that it is then soft and semi-fluid, and that its subsequent firmness is derived from a kind of coagulation; whilst others maintain that it always possesses a considerable degree of firmness and tenacity, and that it must be considered, not only as having a proper independent existence, but as

being the essential part of the tubular fibre. This last view has recently been strenuously contended-for by Prof. Kölliker,* who maintains that we do not distinguish it in the living nerve-tube, merely because it then possesses the same refractive power as the surrounding substance, and who urges the readiness with which it may be brought into view by various reagents (such as concentrated acetic acid, alcohol, ether, iodine, &c.), in nerves taken directly from the living animal, as a proof of the distinctness of its character. The effects of reagents further lead to the suspicion, that the 'axis-band' (this term being preferable to axis-cylinder, since the substance seems more commonly to possess a flattened than a cylindrical form), is of an albuminous nature; and that the 'white substance of Schwann' is the oleaginous constituent of the nerve-fibre. The best evidence of the superior consistence of the axis-band during life, appears to the Author to be derived from the distinct continuity which it may be not unfrequently seen to present when prolonged beyond its envelopes

FIG. 85.




Structure of *Tubular Nerve fibres*, magnified 350 diameters:—A, cylindrical tubuli from nerve; B, varicose tubuli from brain; C, nerve-tubes, of which one exhibits the remains of nuclei in its walls.

(§ 343); and from its occasional fission into finer fibrillæ, the tendency to which subdivision is often marked by a longitudinal striation. Whilst this element of the nerve-fibre is constant, the 'white substance of Schwann' is extremely variable in its amount, and not unfrequently seems to be almost entirely deficient, especially in the 'varicose' tubes, where it is only visible in the varicosities; it may be surmised that the chief purpose served by this substance is the more complete isolation of the 'axis-band.' The membranous sheath itself varies in density in different parts, being stronger in the nervous trunks than in the substance of the brain and spinal cord. In the former, it is not difficult to show that the regular form of the nerve-tube is a perfect cylinder; though a little disturbance will cause an alteration in this,—a small excess of pressure in one part forcing the contents of the tube towards another portion, where they are more free to distend it, and thus producing a swelling. The greater delicacy of the tubular sheath in the latter, causes this result

* "Mikroskopische Anatomie," band ii. p. 393, et seq.

to take place with yet more readiness; so that a very little manipulation exercised upon the fibres of the brain or spinal cord, or on those of special sense, occasions them to assume a *varicose* or beaded appearance (Fig. 85, B), which, when first observed by Ehrenberg, was thought to be characteristic of them. When the fibres of these parts are examined, however, without any such preparation, and especially when they are seen *in situ*, they are found to be as cylindrical as the others.—The diameter of the tubular fibres of the Cerebro-spinal nerve-trunks in Man, usually varies from about 1-2000th to 1-4000th of an inch; being sometimes as great, however, as 1-500th of an inch, and sometimes much below the least of the above dimensions. The fibres decrease in size as they approach the brain, either directly, or through the medium of the spinal cord; and in the brain itself they continue to diminish, as they pass through the medullary towards the cortical portion; so that they are very commonly found of no more than 1-7000th or 1-8000th of an inch in diameter, and sometimes as little as 1-14,000th.—The Sympathetic system contains, with a few tubular fibres of the full size, a great number of much smaller dimensions, ranging from about 1-8300th to 1-4500th of an inch in diameter, and not presenting a distinct double contour, although having a well-defined sharp outline. These were designated by Bidder and Volkmann, who first directed attention to them, the 'fine' fibres; but it is now well ascertained that there is nothing to distinguish them from other fibres of like dimensions elsewhere.

339. Besides these proper *tubular* nerve-fibres,—of which, in combination with areolar and fibrous tissue, blood-vessels, &c. a large proportion of the Cerebro-spinal nerve-trunks are made up,—there are certain other fibres, which are peculiarly abundant in the trunks of the Sympathetic system, and which are of different character from the preceding. They are chiefly distinguished by their small size, their diameter not being above one-half or one-third of that of the ordinary nervous tubuli. They are destitute of the double contour, which has been shown to result in the preceding case from the presence of two distinct substances within the tubular investment; and their substance appears to be homogeneous, or at most but faintly granular, with numerous nuclear corpuscles scattered through it, which, when not originally visible, are brought into view by the agency of acetic acid. When these fibres are aggregated in bundles, they possess a yellowish-grey colour; and they impart somewhat of this hue to the nerve-trunks in which they predominate. Although these fibres, which are distinguished as the 'grey' or 'gelatinous,' exist in greater proportion in the Sympathetic system than in the Cerebro-spinal, yet they are present in great numbers in some of the trunks of the latter, the Olfactive nerves being almost entirely composed of fibres presenting their most essential characters;* and they even seem to be frequently continuous with the ordinary tubular fibres, especially with those of smallest diameter. They may be traced into the ganglia of the Sympathetic, into the ganglia on the posterior roots of the Spinal nerves, and even to the ganglionic matter of the Brain and Spinal Cord.†

* See Messrs. Todd and Bowman's "Physiological Anatomy," vol. ii. p. 9.

† Much controversy has taken place in Germany, regarding the existence of a set of fibres peculiar to the Sympathetic system. The *grey* or *gelatinous* fibres, described by Remak, and (following him) by Müller and others, as essentially constituting the 'organic' system of

340. The second primary element of the Nervous system, without 'hich the fibrous portion would seem to be totally inoperative, is comosed of nucleated *Cells* or *Vesicles*, containing a finely granular substance, ad lying somewhat loosely in the midst of a minute plexus of bloodessels. Their original form may be regarded as globular; whence they ave been called ganglion-globules. This, however, is liable to alteration; ›metimes, perhaps, from external compression; but more commonly rough their own irregular mode of growth. They frequently extend hemselves into long processes, which may give them (according to the umber thus projecting) a 'caudate' or a 'stellate' form (Fig. 86). These

Fig. 86.


Various forms of *Ganglionic Vesicles*:—A, B, large stellate cells, with their prolongations, from the anterior horn of the grey matter of the Spinal Cord;—C, nerve cell with its connected fibre, from the anastomosis of the facial and auditory nerves in the Meatus auditorius internus of the Ox; *a*, cell-wall; *b*, cell-contents; *c*, pigment; *d*, nucleus; *e*, prolongation forming the sheath of the fibre; *f*, nerve-fibre:—D, nerve-cell from the substantia ferruginea of Man:—E, smaller cell from the Spinal Cord. Magnified 350 diameters.

rocesses are composed of a finely-granular substance, resembling that of he interior of the vesicle, with which they seem to be distinctly coninuous. They are very liable to break off near the vesicle; but if traced o a distance, they are found to divide and subdivide, and at last to give ff some extremely fine transparent fibres; some of which seem to inosculate with those of other stellate cells, whilst others become continuous vith the axis-cylinders of tubular fibres, or with gelatinous fibres. Such 'esicles are seen alike in the ganglionic masses of the Cerebro-spinal, and n those of the Sympathetic system.—Besides the finely-granular subtance just mentioned, these cells usually contain a collection of pigment-

Nerves, have been affirmed by several eminent authorities not to be entitled to the designaion of nerve-fibres at all, but to be a form of simple fibrous tissue; and the *fine* tubular bres described above, were considered by Bidder and Volkmann to be the peculiar constiuents of the Sympathetic system. Further researches, however, seem to have removed all oubt as to the real nature of the gelatinous fibres; as their continuity with the stellate rolongations of the ganglionic cells, and with the tubular fibres, is now established by the oncurrent testimony of many excellent observers.—For a valuable summary of this contro'ersy, see Dr. Sharpey's Introduction to "Quain's Elements of Anatomy," p. ccxxvii.

granules, which especially cluster round the nuclei, and give them a reddish or yellowish-brown colour. This pigment seems to have some resemblance to the hæmatine of the blood; and it is usually, if not invariably, deficient among the Invertebrata, as well as less abundant in Reptiles and Fishes. The vesicles are sometimes covered with a layer of a soft granular substance, which adheres closely to their exterior and to their processes; this is the case in the outer part of the cortical substance of the human brain. In other instances, each cell is inclosed in a distinct envelope composed of smaller cells, closely adherent to each other, and to the contained cell; such an arrangement is common in the smaller ganglia, and in the inner portion of the cortical substance of the brain.—The diameter of the vesicles is extremely variable, owing to the changes of form above described; that of the globular cells is usually between 1-300th and 1-1250th of an inch.

341. In the central or ganglionic masses of the Nervous system, we find these vesicles aggregated together, and imbedded in a finely-granular matter; the whole being traversed by a minute plexus of capillary blood-vessels. The entire substance, made up of these distinct elements, is commonly known as the *cineritious* or *cortical* substance; being distinguished by its colour, in Man and the higher animals at least, from the *white* substance composed of nerve-tubes, of which the trunks of the nerves, as well as a large part of the brain and spinal cord, are made up; and occupying in the brain a position external to the latter, which is often termed the *medullary* substance. This position, however, is quite an exceptional one; for in the spinal cord and in the scattered ganglia of Vertebrated animals, and in all the ganglionic centres of Invertebrata,—everywhere, in fact, except in the Brain,—the vesicular nerve-substance occupies the centres of the ganglia; consequently the terms 'cortical' and 'medullary,' as applied to the vesicular and tubular substances respectively, are quite inappropriate. Nor are the designations, that have reference to their colour, much more uniformly correct: for, as we have seen, the vesicular substance may be destitute of internal pigment-granules, and the blood in its capillary plexus may be pale or colourless; so that the reddish-grey hue, which is expressed by the term 'cineritious,' may be entirely wanting; whilst, on the other hand, we have seen that certain of the nerve-fibres, making up what is commonly termed the 'white' substance, are of a grey colour. Hence the only valid distinction between these two kinds of nervous matter, is that which has reference to their constitution;—as consisting of *cells* or *vesicles* on the one hand, or of *tubes* or *fibres* on the other.

342. The connection between the 'fibrous' and the 'vesicular' elements, in the Nervous Centres, is a question to which great attention has been paid for some time past by Microscopic observers; but it is one of such intricacy and difficulty, that it is still far from being satisfactorily elucidated. It is certain, however, that *some* of the nerve-fibres come into direct continuity with the ganglionic cells or vesicles; and two principal modes of such connection have been observed. Some of the fine granular prolongations of the 'stellate' nerve-cells, are traced into the form of 'gelatinous' fibres; and these, at a greater distance from their centre, exhibit more and more of the tubular character, and at last become ordinary 'tubular' fibres. On the other hand, a spheroidal

vesicle is often observed to be directly continuous with a tubular fibre, the transparent membranous envelope of the latter being a prolongation of the cell-wall, and the substances which it contains being in connection with those included within the cell-cavity (Fig. 86, c). According to Prof. Kölliker,* it is rare among the higher animals for a single vesicle to be thus connected with more than one nerve-tube, although two or more are frequently found to issue from the same corpuscle in Fishes and Reptiles; and he regards the remaining prolongations of the stellate cells in the light of *nervi nervorum.* It appears certain, however, that there are many ganglionic vesicles which do not possess any such connection with nerve-fibres; whilst, on the other hand, it seems possible that there may be nerve-fibres which have no such central terminations, but which simply enter the ganglionic masses, pass around and amongst the cells, and then emerge without having undergone any distinct change, save that they present a soft and varicose appearance whilst threading their way between the vesicles. This appearance, according to Mr. Newport, may be distinguished in the ganglia of the dorsal column of Articulated animals.†—As yet, nothing is certainly known of the purposes to which these different modes of connection are respectively subservient.

343. The mode in which the Nerve-fibres terminate, at their *peripheral* extremities, seems not to be always the same. It has been already shown that the *motor* fibres, which are distributed to the muscles, have no proper terminations; a series of loops, returning into themselves or joining others, being formed by the ultimate ramifications of the main trunks (§ 309). These loops in Man seem to be formed by complete tubular fibres; but in some of the lower animals (as the Frog), the 'axis-band' seems to pass beyond its envelopes, and to split up into more minute fibrillæ.—So in the tactile papillæ of the Human Skin, the looped termination of the fibres (Fig. 87) can ordinarily be well made out by the method described by Prof. Kölliker (§ 239); but in the tail of the Tadpole, as also in the mesentery of the Amphibia, it was first observed by Schwann,‡ and has been since confirmed by Dr. Sharpey,§ that the ordinary primitive nerve-fibres, after separating from the fasciculi, divide into fibrils of much smaller size, bearing a strong resemblance to the 'gelatinous' kind, which spread out in various directions, and form a

* See his 'Neurological Observations' in "Kölliker and Siebold's Zeitschrift" for 1849, and his "Mikroskopische Anatomie," band ii.

† Certain observations which have been made upon the Nervous system of fœtuses, in which the brain and spinal cord were wanting, confirm the idea that this is one of the modes in which the nerve-trunks come into connection with their ganglionic centres. The nervous cords were for the most part developed; and at their (so-called) origins or central extremities, they were found to hang as loose threads in the cavities of the cranium and spine. On examining these threads, it was found that the nerve-tubes, of which they consisted, formed distinct loops; each of which was composed of a fibre that entered the cavity, and then returned from it. These loops were imbedded in granular matter, resembling that interposed between the vesicles in the cortical substance of the brain, and perhaps to be regarded as vesicular matter in an early stage of its formation. All that is known of the laws of formation of such irregular productions, leads to the belief, that we may rightly consider this arrangement of the nerve-tubes as one which exists in the nervous centres, when they are normally developed. (See Dr. Lonsdale, in "Edinb. Med. and Surg. Journal," No. 157; and Mr. Paget in "Brit. and For. Med. Rev.," No. 43, p. 273.)

‡ "Medizinischen Zeitung," Aug., 1837.

§ Introduction to "Quain's Elements of Anatomy," p. ccxviii.

plexus not unlike that of the capillaries. The origin of these plexuses has been traced by Prof. Kölliker;* who has found that they are formed, like capillary plexuses (§ 294,) by the inosculation of the prolongations of radiating cells, whose centres are at a considerable distance from each other. Looped terminations may be seen in the nerves supplying the

Fig. 87.

Distribution of the *Tactile Nerves* at the extremity of the Human Thumb, as seen in a thin perpendicular section of the skin.

dental sacculi, and in those of the conical papillæ of the tongue; on the other hand, in the fungiform papillæ of the tongue, the Author, after a very attentive search for them (in conjunction with Messrs. Bowman, Kiernan, and T. Wharton Jones), could not succeed in distinguishing them; no free extremities, however, were discernible; and some appearances were seen, which indicated that the axis-band is here also prolonged beyond its envelopes, and is continued as a gelatinous fibre into the tissue at the apex of the papilla, where it ceases to be distinguishable.—It will hereafter be shown, that in the Retina, in some parts of the internal Ear, and perhaps also on the Olfactory surface, the peripheral fibres come into relation with true ganglionic cells; and it may be questioned whether it be not as requisite for the reception of any other kind of *sensory* impressions than those of a mere mechanical nature, that a ganglionic vesicle, or its equivalent under some other aspect, should be in connection with the *peripheral* expansions of the sensory nerves, as it is for the origination of *motor* impulses, that ganglionic vesicles should be in relation with them in the central organs.

344. One very peculiar mode of termination of certain of the Nervous fibres, the physiological import of which, however, is entirely unknown, is in the bodies termed *Pacinian*, after Pacini, the first writer who gave an account of their internal structure, and demonstrated their essential connection with the nervous fibres. His researches have been followed up by Henlé and Kölliker,† and also by Mr. Bowman.‡ These bodies are found in considerable numbers attached to the branches of the nerves of the hand and foot, as they pass through the subcutaneous fat in their way to the skin (Fig. 88, B); they are also occasionally met-with on subcutaneous nerves elsewhere, and they have been discovered on the nerves of the solar plexus in the abdominal cavity. Their form

* "Annales des Sciences Naturelles," Zool., Août, 1846.
† "Ueber die Pacinischen Körperchen," Zurich, 1844.
‡ "Cyclopædia of Anatomy and Physiology," Art. 'Pacinian Bodies,' and Todd and Bowman's "Physiological Anatomy," vol. i. p. 395.

usually approaches to the oval, though they are generally more or less curved or reniform; and their mean size in the adult is from 1-15th to 1-10th of an inch in length, and from 1-26th to 1-20th of an inch in breadth. They are attached to the branches of the nerves on which they cluster, by slender peduncles, each of which consists of a single tubular nerve fibre, with one or more fine blood-vessels, and a sheath of areolar tissue (Fig. 88, A, *a*, *b*). The corpuscle itself consists of numerous concentric capsules, of a delicate fibrous membrane, enclosing each other like the coats of an onion, to the number, sometimes, of between forty and sixty; those which form the internal portion (*c*) being closer together than those of the outer part (*d*). These capsules are kept apart by a transparent fluid (probably albuminous), which also occupies the central cavity. The nerve-fibre gradually loses its neurilemma as it passes through the series of capsules, but still retains its dark double contour until it enters the cavity; from that point, however, it presents the characters of the 'gelatinous' fibres, being pale, flattened, granular, and destitute of a tubular envelope; and this it usually retains as far as its termination. The fibre usually ends in a sort of knob at the farthest extremity of the capsule; sometimes, however, it bifurcates, and each division ends in a similar knob; and still more rarely, it separates into three parts (*f*).—The constant presence of these bodies, in certain regions of the body, in perfectly healthy individuals of all ages, and even in the fœtus, is quite sufficient to negative the idea put forward by Cruveilhier and others, that they are morbid or accidental productions, probably resulting from pressure applied to the nerves. On the other hand, the suggestion of Pacini, adopted by Henlé and Kölliker, that they are analogous in function to the electrical organs of Fishes (to which they bear a certain degree of structural resemblance), has no sufficent evidence in its favour.

Fig. 88.


Human *Pacinian Corpuscles*:—A, single corpuscle, highly magnified, showing *a* its peduncle, *b* its contained nerve-fibre; *c*, outer layers and *d* inner layers of the capsule; *e*, nerve-fibre become pale in its passage through the interior of the corpuscle; *f*, its subdivision and termination:—B, portion of digital nerves with Pacinian corpuscles attached, rather less than the natural size.

345. The Chemical constitution of the Nervous matter is peculiar, but has not yet been satisfactorily made out. An acquaintance with its general features is of importance, however, in leading us to recognise in the excretions the results of its decomposition.—The following, according to L'Heritier,*

* "Traité de Chimie Pathologique," p. 596.

is the relative proportion of the different constituents in individuals of different classes:—

| | Infants. | Youths. | Adults. | Aged Persons. | Idiots. |
|---|---|---|---|---|---|
| Water | 82·79 | 74·26 | 72·51 | 73·85 | 70·93 |
| Albumen | 7·00 | 10·20 | 9·40 | 8·65 | 8·40 |
| Fat | 3·45 | 5·30 | 6·10 | 4·32 | 5·00 |
| Osmazome* and Salts | 5·96 | 8·59 | 10·19 | 12·18 | 14·82 |
| Phosphorus | 0·80 | 1·65 | 1·80 | 1·00 | 0·85 |

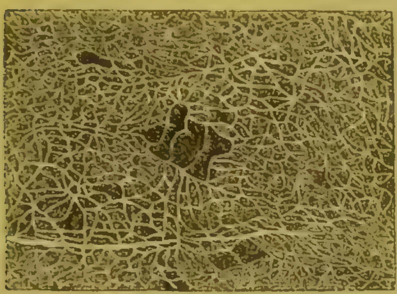
According to M. Fremy, the Phosphorus is combined with part of the fatty matter; and forms with it two peculiar fatty acids, termed by him the *Cerebric* and *Oleophosphoric* (§ 44).—Cholesterin has also been extracted from the brain by M. Fremy in considerable quantity; and is perhaps to be regarded as one of the products of its disintegration (§ 43).—The proportion of Fixed Salts is about 3½ parts in 100 of dry Cerebral matter; the nature of these has not yet been satisfactorily determined, but they seem to be chiefly alkaline phosphates and carbonates.—According to Lassaigne, the chemical composition of the 'cortical' and 'medullary' substances of the brain is essentially different; the former containing 85 per cent of water, whilst the latter has only 73; the cortical substance having also 3·7 per cent of a red fatty matter, of which the medullary has scarcely any; and being almost entirely destitute of the white fatty matter, which exists in large proportion in the latter.—The *Albuminous* matter in the above analyses probably constitutes the *walls* of the nerve-cells and nerve-tubes (as well as of the capillary blood-vessels), and that portion of their *contents* which is represented in the nerve-tubes by the 'axis-band'; whilst the *phosphorized fats* seem to form the 'white substance of Schwann' in the tubular fibres, and a considerable part of the contents of the vesicles.—It will be remarked, that the amount of phosphorus is the greatest at the period of greatest mental vigour; and that in infancy, old age, and idiocy, the proportion is not above half that which is present during the adolescent and adult periods.

346. The Nervous System is very copiously supplied with *Blood-vessels;* the arrangement of which varies according to the form of the elementary parts in which they are distributed. Thus in the Vesicular substance of the nervous centres, the capillaries form a minute net-work (Fig. 89), in the interstices of which the ganglionic cells are included. In the Fibrous substance, the capillaries are distributed much on the same plan as in Muscular tissue (Fig. 80); the net-work being composed of straight vessels, which run along the course of the fibres, passing between the nerve-tubes, and which are connected at intervals by transverse branches. And at the sensory extremities of the nerves, we find loops of capillaries (Fig. 90) arching over their terminal and probably looped filaments.—The Brain of Man, taken *en masse*, has been estimated to receive one-sixth of the whole amount of blood, although its weight is not usually more than one-fortieth part of that of the entire body. Whether or not this estimate be precisely correct, there can be no doubt that it receives far more blood than any other part containing the same amount

* It is probable that, in the above analyses of L'Heritier, the Cerebric acid, which is not soluble in ether, is included under the head of Osmazome; for the analyses of Denis and other chemists give a much higher proportion to the Phosphorized Fat, and a much smaller one to the ill-defined compounds represented by the designation Osmazome.

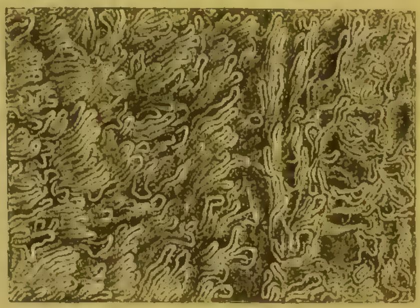
of solid matter. Now this copious supply of blood evidently has reference to two distinct objects; first, to supply the necessary conditions for the *action* of the Nervous system; and, secondly, to maintain its *nutrition.* Many circumstances lead to the conclusion, that, in the Nervous as in the Muscular system, every vital operation is necessarily connected with a

Fig. 89.



Capillary net-work of *Nervous Centres.*

Fig. 90.



Distribution of Capillaries of the surface of the *Skin* of the finger.

certain change of composition, so that no manifestation of nervous power can take place, unless this change can be effected (§§ 358—362). There is strong reason to believe, further, that this change essentially consists in the union of Oxygen conveyed by the arterial blood, with the elements of the proper Nervous matter: and that this union consequently involves the death and disintegration of a certain amount of the tissue, the reproduction of which, therefore, will be requisite, in order that the system may be maintained in a state fit for action. This reproduction is effected by the nutritive process, which takes place at the expense of other constituents of the blood; and it will proceed most vigorously in the intervals, when the active powers of the nervous system are not being called into operation.—The proofs of this continual waste and reproduction of the Nervous substance, are partly afforded by the appearance of the products of its decomposition in the excretions, and by the demand which is set up for the materials for its reparation; these being found to accord in amount, as will be shown hereafter, with the degree of its functional activity. But evidence of another kind may be drawn from the microscopic appearances presented by the cortical substance of the Brain. For ganglionic vesicles may be observed in all stages of development; and numerous bodies resembling free nuclei are seen in the granular substance in which these are imbedded. It is surmised by Henlé,* from the comparative aspects of the external and internal layers of the cortical substance, that there is as continual a succession of nerve-cells, as there is of epidermic cells; their development commencing at the surface, where they are most copiously supplied with blood-vessels from the pia mater; and proceeding as they are carried towards the inner layers, where they come into more immediate relation with the tubular portion of the nervous tissue. This change of place is probably due to the continual death and disintegration of the mature cells, where they are connected with the fibres, and the equally rapid production of new generations at the external surface;—the newly-formed Ganglionic cells being thus

* "Traité d'Anatomie Générale," traduit par Jourdan; tom. ii. p. 330.

carried inwards, in precisely the same manner that the Epidermic cells are carried outwards (§ 240).

347. The maintenance of the integrity of the Nervous tissue, by the due performance of the nutritive operations, is not less dependent than that of the Muscular (§ 313), upon the continuance of its functional activity; indeed it will be presently shown, that degenerative changes manifest themselves at a much earlier period after the interruption of that activity, so as to indicate that the dependence is yet closer.—It has long been known that, when disease of the Optic nerve or of its ganglionic centre occasions complete Amaurosis, the Retina comes in time to lose its characteristic appearance, and the portion of the Nerve in front of the seat of the disease presents an atrophied aspect. And it has been shown by Valentin,* that, notwithstanding the general appearance of the eye may be unchanged, the texture of the retina becomes completely altered; for it is found to be composed of white cylindrical threads interlaced together, without presenting any appearance of the ganglionic vesicles or of the tubular nerve-fibres proper to the part; and the yellow spot of Soemmering becomes paler, and is at last indistinguishable. But if a very slight degree of sensibility to light remain (showing that some power of transmission still exists in the optic nerve), these changes are much less decided. Further, when the sight is destroyed by a disease or injury which prevents the light from passing through the pupil, the whole eye becomes more or less atrophied; and the retina and optic nerve are found after death (if the morbid condition have lasted sufficiently long) to have lost their characteristic structure. It is probable that in the latter case, as in that of Muscles long disused, a renewal of the normal nutrition, and a re-establishment of the structural and functional integrity of the tissues, takes place (provided the degeneration have not proceeded too far), when light is again allowed to act upon the retina. For it may be observed that, when an eye has been from any cause withdrawn for a long period from its normal state of activity, and is again placed in a condition to be employed (as when it has been turned inwards by extreme Strabismus, and has been brought by operation into the correct axis; or when closure of the pupil, or the extension of an opacity over the central part of the cornea, has been remedied by making an artificial pupil), the recovery of good sight is by no means immediate, but often requires a considerable lapse of time, like the recovery of muscular power in a limb which has become atrophied from paralysis.—Various experimental results confirm this view. Thus it was found by Gunther and Schön, that when a nerve is divided, the peripheral portion exhibits obvious degenerative changes within the space of a week;† and these changes have been shown by Nasse to be still more decided some months afterwards.‡ The most minute and interesting researches yet made upon this point, however, are those of Dr. Aug. Waller;§ who has taken for the subject of his investigations the alterations produced in the nerves of the Frog's tongue, the papillæ of which are supplied by the glosso-pharyngeal. Within three or four days after

* "De Functionibus Nervorum Cerebralium, et Nervi Sympathetici," Bernæ, 1839.
† "Müller's Archiv." 1840, p. 276.
‡ Op. cit., 1839, p. 409.
§ "Philosophical Transactions," 1850, p. 423, et seq.

the division of the trunk of this nerve on one side, a difference begins to manifest itself between the fibrils contained in the papillæ which it supplies, and those of the sound side; for a slightly turbid or coagulated appearance is seen in the contents of the tubes, which no longer appear to fill them; and the difference is still more marked twenty-four hours after death. About five or six days after the section, the alteration of the nerve-tubes, produced by the coagulation of their medullary contents, becomes very obvious; the diameter of the altered tubes is about a fourth less than that of the sound ones; and in many parts, the membranous tubules cannot be distinguished, the coagulated masses appearing to be completely disjointed from one another. On the eighth and ninth days the coagulated particles become still more disconnected, and are in parts removed by absorption; on the tenth day, the particles begin to assume a granular texture; and by about the twentieth day they are completely reduced to the granular state, the presence of the nervous element being only indicated by rows of numerous dark granules, arranged like the beads of a necklace. The resistance of these granular bodies to chemical agents has been found by Dr. Waller to be most remarkable; they remain unaffected by acids, alkalies, and ether; and he has seen them apparently unaltered after a lapse of more than five months.—As all the nutritive changes in cold-blooded animals go on with greater rapidity at a high than at a low temperature, so should we expect that the degenerative changes would likewise, upon the principles formerly laid down (§ 114); and it is an interesting confirmation of this view to find, that Dr. Waller has noticed that the alterations consequent upon section of the nerves, make themselves apparent in frogs much earlier in summer than they do in winter.

348. The first *development* of the *Nerve-tubes* appears to take place, like that of Muscular fibre, by the coalescence of a number of primary cells into a continuous tube; for although the primary nervous cell has not yet been made out with precision, the nuclei of what seem to be the original cells may frequently be seen in the fully-formed tube, lying between their membranous walls and the white substance of Schwann (Fig. 85, c). When first a nerve-fibre can be recognised as such, it has a strong resemblance to the 'gelatinous' fibres of the sympathetic trunks; being a cord of small diameter, without any clear distinction between the tube and its contents, of granular consistence, and having nuclei at no great distance from each other. The substance of the fibre, at this period, seems to correspond with the axis-band of the fully-formed nerve-tube; the white substance of Schwann is subsequently deposited around it, separating it from the membranous tubular envelope.—The statements of Schwann and Kölliker respecting the origin of the peripheral plexuses, have been already referred to (§ 343). It is believed by the last-named observer (loc. cit.), that the fibres of the trunks with which these plexuses become connected, originate in cells which become fusiform by elongation, and which then coalesce at their extremities; and these seem to increase, after the first formation of the trunks, by the longitudinal subdivision of fusiform cells which had not previously undergone complete metamorphosis into fibres, or by the development of cells *de novo*.—The first development of the *vesicular* substance appears to take place on the same plan with its subsequent renewal; that is, from free nuclei, around which

the intervening granular matter seems to collect, the cell-walls being of subsequent formation.

349. The *regeneration* of Nervous tubuli which have been destroyed, takes place in continuity with those which have been left sound. This is readily proved, on the one hand, by the return of the sensory and motor endowments of the part whose nerves have been separated; and on the other, by microscopic examination of the reunited trunks themselves. All our knowledge of the functions of the Nervous System leads to the belief, that *perfect continuity* of the Nerve-tubes is requisite for the conduction of an impression of any kind, whether this be destined to produce motion or sensation; and various facts, well known to Surgeons, prove that such continuity may be re-established after it has been completely interrupted. In the various operations which are practised for the restoration of lost parts, a portion of tissue removed from one spot is grafted (as it were) upon another; its original attachments are more or less completely severed, frequently altogether destroyed, and new ones are formed. Now, in such a part, so long as its original connections exist, and the new ones are not completely formed, the sensation is referred to the spot from which it was taken; thus, when a new nose is made, by partly detaching and bringing down a piece of skin from the forehead, the patient at first feels, when anything touches the tip of his nose, as if the contact were really with the upper part of his forehead. After time has been given, however, for the establishment of new connections with the parts into whose neighbourhood it has been brought, the old connections of the grafted portion are completely severed, and an interval ensues during which it frequently loses all sensibility; but after a time its power of feeling is restored, and the sensations received through it are referred to the right spot. A more familiar case is the regeneration of Skin, containing sensory nerves, which takes place in the well-managed healing of wounds involving loss of substance. Here there must obviously be, not merely a prolongation of the nerve-tubes from the subjacent and surrounding trunks, but also a formation of new sensory papillæ. A still more striking example of the regeneration of Nervous tissue, however, is to be found in those cases (of which there are now several on record) in which portions of the extremities, that have been completely severed by accident, have been made to adhere to the stump, and have, in time, completely recovered their connection with the Nervous as with the other systems, as is indicated by the restoration of their motor and sensory endowments.—The evidence is still more satisfactory, however, when it is furnished not merely by the return of functional activity, but by structural examination of the divided part. This investigation has been recently pursued by M. Brown-Séquard, with very surprising results. Having divided the Sciatic nerve of a Guinea-pig, he observed indications of a return of sensibility in the limb supplied by it, as early as a month after the operation; within another month, the sensibility had decidedly augmented, though it was still much inferior to that of the sound limb, and the muscles then began again to act; six months after the section, the sensibility appeared to have completely returned, and the motor power to have been almost entirely recovered; and at the end of eleven months, no difference could be discovered in the motor power of the two limbs. The animal was killed twelve months after the operation; and a

careful examination having been instituted into the state of the part of the nerve where the division had been made, no indication of the division could be discovered, either with the naked eye, or with the microscope. The usual swelling at the point of reunion had been distinguishable up to about the sixth month; but it had then disappeared.—The results of M. Brown-Séquard's experiments upon the Spinal Cord are yet more striking. The spinal cord of a pigeon having been divided between the fifth and sixth dorsal vertebræ, the completeness of the section was manifested by the entire paralysis of the posterior part of the body, as regarded both sensation and voluntary movement; at the end of three months, however, voluntary movements began to show themselves in the midst of reflex actions, and sensibility also reappeared; these powers gradually augmented, and six months after the operation the bird could stand for some minutes, though it fell if it attempted to walk; in the course of the seventh month it began to walk, but unsteadily, helping itself by its wings; by the end of the eighth month it could walk slowly without support, though it fell over if it attempted to walk fast, unless it supported itself by its wings; twelve months after the operation, it could run; and at the end of the fifteenth month its progression seemed in all respects normal, save that a certain degree of stiffness remained in its gait. In several other cases, in which a partial section of the spinal cord had been made, and in which a complete return of functional power had taken place, a careful examination was made of the divided part; this was distinguishable by a whitish cicatrix, the substance of which was found to be in great part made up of fibres of areolar tissue, the direction of which was transverse or oblique; but these were crossed by great numbers of nerve-tubes running in a longitudinal direction, which exhibited the characteristic double contour, and were uninterruptedly continuous through the whole extent of the cicatrix; and amongst these were scattered some ganglionic corpuscles.*

350. *Functions of Nervous Tissue.*—The peculiar vital endowments of the Nervous tissue can only be exhibited, when the two distinct forms of it are united in such a manner as to constitute a 'nervous system.' This system in its simplest condition, is composed of an *expansion of nerve-fibres* over the surface of the body, or of some part of it; of *an afferent trunk* formed by the junction of these fibres, which proceeds towards a ganglion

* See the "Gazette Médicale," 1849, No. 45, and 1851, No. 30; also the "Comptes Rendus de la Société de Biologie," 1849, 1850.—The successful issue of these experiments is in great part attributable to the sedulous care bestowed by M. Brown-Séquard upon the animals which are the subjects of them. It frequently happens that pathological changes take place in the paralyzed parts, which may lead to serious or even fatal consequences; and such changes have been attributed to the direct influence of the withdrawal of nervous power, upon the nutritive processes. It has been shown, however, by an experiment of M. Brown-Séquard's, that no such influence exists; and that the pathological changes in question are due to the want of power on the part of the animals to withdraw their limbs from sources of injury. For having divided the sciatic nerve in a number of rabbits and guinea-pigs, he placed some of the animals at liberty in a room with a paved floor, whilst he confined others in a box, whose bottom was thickly covered with bran and hay. In a fortnight, the former set exhibited an obvious disordered action in the paralysed limbs, the claws being entirely lost, the extremities of the feet swollen, and the exposed tissues red, engorged, and covered with fleshy granulations; and at the end of a month these alterations were more decided, the bones being denuded, and necrosis having commenced in them. On the other hand, among the animals confined in boxes with a soft floor, no such injuries had accrued.

wherein it terminates; of a *ganglionic centre* containing vesicular nervous matter, with which the nerve-fibres come into connection; of an *efferent trunk*, issuing from the ganglion, and proceeding towards the muscles; and of a *plexus of fibres* into which that trunk subdivides, and which comes into intimate relation with the elements of the Muscular tissue.—Such an apparatus, altogether designated as the 'nervous circle,' seems to constitute the entire Nervous System of some among the lower animals; and it may be multiplied to any extent, so as to supply a great number of similar organs (as we see in the circular gangliated cord surrounding the mouth of the Star-fish, and the double gangliated column which extends along the body of the Worm or the Centipede), without any essential change in its endowments. And even in Man, we shall hereafter find that a considerable part of the Nervous system is constructed upon this simple plan; although its uniformity is obscured by the frequent coalescence of ganglionic centres that remain distinct in the lower animals, and by the greater variety in the distribution of the nerve-trunks, in accordance with the dissimilarity between the several organs with which they are connected.—The *modus operandi* of such a system is as follows. By contact, pressure, or some other form of mechanical agency, an *impression* is made upon the peripheral extremities of the *afferent* nerves; and this impression, or rather, the change induced by it in the condition of the nerve-fibre, is *transmitted* by the nerve-trunk to the central ganglion. In this ganglion, the influence transmitted by the afferent trunk excites a *reactive change;* the occurrence of which is indicated by the *transmission,* along the *efferent* nerves, of an influence, which being distributed to the muscular substance, excites it to *contraction.* All this takes place so instantaneously, that the movement follows immediately upon the application of the stimulus. Actions of this kind, which do not involve Sensation as one of their conditions, and which are executed in direct and unconscious respondence to external stimuli, are now generally termed 'reflex;' though the designation 'excito-motor' (originally proposed by Dr. M. Hall) would perhaps be more appropriate, as distinguishing this class of actions from others which have an equal claim to the term 'reflex.'

351. Such operations as the foregoing, however, must be considered as constituting the lowest kind of functional activity of the Nervous system; since they serve only an *internuncial* purpose, that of bringing the different parts of the bodily organism into co-operative relationship with each other. A much higher attribute is that by which it brings the conscious Mind into relationship with the body, and, through its medium, with the external world; informing it, through the impressions received by the organs of sensation, of the changes which the material objects around it undergo; and enabling it to react upon these, by the instrumentality of its motor apparatus. Certain ganglionic centres, distinct from those of simply-reflex action, are set apart for these purposes; but we can trace no essential peculiarity in their structure, which can in any way indicate their possession of this extraordinary endowment. They still consist of vesicular matter, with afferent or sensory nerve-trunks terminating in them, and with efferent or motor trunks issuing from them: and our assurance, that it is through their instrumentality that the mind is affected by external impressions, rests upon the fact, that if an interruption exist in the transmission of the influence to which those changes give

rise, at any point whatever between the periphery and the central ganglion, those impressions are not felt; whilst, conversely, any interruption along the course of the efferent fibres, prevents the influence of psychical states from producing any respondent contractions in the muscles.—The simplest mode in which the Nervous system is subservient to mental changes, is in that affection of the *consciousness* which is directly consequent upon external impressions, and is designated as *sensation;* and the part of the apparatus in which this conversion is effected, is termed the *sensorium.* We shall hereafter see that this 'sensorium' probably consists in Man of a number of distinct ganglionic centres, each of which is the instrument of some one special kind of sensorial change. From these sensory ganglia, also, motor fibres proceed to the muscles; and through their instrumentality, movements may be produced by the re-action of the ganglionic centres to the impressions made upon them. Such movements, however, being only called forth through the intermediation of sensation, are distinguished as 'sensori-motor' or 'consensual.'—Superadded to the mere sensorium, however, in Man and all the higher animals, we find certain other ganglionic masses, the Cerebral hemispheres, whose functional relation to the operations of mind is yet more intimate; for these appear to be the instruments of all the higher psychical operations, the formation of ideas, the excitement of the emotions, the acts of combination, comparison, and judgment, the determinations of the will, &c. They receive their first stimulus to action, not from impressions transmitted to them directly from the peripheral organs, but from an agency sent up to them from the sensorial centres; and it seems probably to be, in like manner, through an agency reflected downwards to those centres, and acting through their instrumentality, that the influence of the will, of emotional states, &c., is transmitted to the motor apparatus.—Thus we see that the nervous force, itself excited by impressions of a physical nature, can determine mental changes; whilst, conversely, certain states of mind, by exciting the nervous force, can effect changes in the bodily fabric, and, through this, upon the external objects within its reach.

352. The instrumentality of the Nervous system is not limited, however, to the excitation of mental activity on the one hand, or to that of muscular contraction on the other; for the peculiar agency which it exerts is found to have an intimate relationship with all the other manifestations of vital force, which the animal organism exhibits. So intimate, indeed, is this relationship,—so obvious is the influence which nervous agency exerts over the operations of Nutrition, Secretion, &c., especially in the higher animals,—that many physiologists have regarded them as essentially *dependent* upon it. For this assumption, however, there is no valid evidence; and the whole tendency of recent discovery has been (as we have seen) to establish the doctrine of the *essential independence* of the vital endowments of each integral part of the fabric. And all the phenomena which have been supposed to indicate the necessity for nervous agency, as a condition of acts of growth, development, &c., are equally explicable upon the doctrine here advocated; which affords a definite scientific expression of them. For, just as Electricity, developed by Chemical change, may operate (by its correlation with chemical affinity) in producing other chemical changes elsewhere,—so may Nerve-force, which has its origin in Cell-formation, excite or

modify the process of cell-formation in other parts, and thus influence all the vital manifestations of the several tissues, whatever may be their own individual characters. This expression is also available for the well-known influence of *mental* states upon the properties of the various tissues and the composition of the secretions; since this influence can only be exerted through the instrumentality of the nervous apparatus.—Further, it not only appears that a simple withdrawal or disturbance of the nervous force supplied to particular organs, occasions a retardation or perversion of their vital operations; but there also seems evidence that an influence of an *opposite kind* may be transmitted through the nervous system, which is positively and directly antagonistic to the exercise of the vital powers of the several tissues. Such, at least, appears to be the only legitimate mode of accounting for the extraordinary effect of 'a shock,' physical or mental, in at once and completely destroying the contractility of the heart, and in bringing to a stand the vital operations of other parts (§ 321). And it harmonizes well with the fact, that, in Hemiplegia, the 'palsy-stroke' transmitted from the brain along the spinal cord, almost invariably affects the leg less injuriously than the arm, and for a shorter duration; recovery taking place soonest in the leg, even when it has been at first paralysed as completely as the arm. If the Nervous force be regarded as a *polar* force (§ 364, *note*), analogous in its mode of transmission to Electricity, it is not difficult to understand that the *reversal* of the usual direction of its action may produce the effects in question; especially when it is borne in mind, that the *direct* and *inverse* electric currents (as shown by Prof. Matteucci) exert opposite influences upon the nervous excitability.*

353. The manifestations of nerve-force are almost invariably excited by the agency of *stimuli*, which operate upon the peripheral origins of the afferent nerves, and upon the central origins of the efferent. In the cases already referred to, the stimulus whose influence, conveyed to the central ganglia, excited sensations or respondent movements, was that of mechanical *Motion;* and this is equally effectual when applied to the *trunks* of the afferent nerves, as by pinching or pricking them. But other physical agencies produce corresponding results. Thus *Heat*, applied to a sensory surface, excites the nerve-force of the afferent nerves, by whose instrumentality such a change is produced in the sensorial centres, as renders us conscious of the external alteration. The power of *Light*, moreover, to excite nerve-force, is clearly indicated by its influence upon the optic nerve through the instrumentality of the retina.† So, again, the stimulating agency of *Chemical Affinity* is made apparent by the pain which results from the application of strong re-agents to the

* The *direct* current is that which is transmitted along a motor nerve in the direction of its ramifications; the *inverse*, that which is transmitted from the periphery towards the centre. The 'direct' current rapidly *weakens* and at last *destroys*, the excitability of a nerve; so that, when it has traversed the lumbar nerve of a frog for twenty or thirty minutes, there are no further contractions, either on opening or closing the circuit. On the other hand, the passage of the 'inverse' current augments the excitability within certain limits; and restores that which has been exhausted by the direct current. (See Prof. Matteucci's "Lectures on the Physical Phenomena of Living Beings," translated by Dr. Pereira, p. 262.)

† It seems to be the want of this intermediate ganglionic apparatus (§ 343), which prevents Light from acting upon the *trunks* of the sensory and motor nerves, after the manner of Heat.

extremities or to the trunks of the sensory nerves. But of all the physical forces, *Electricity* has the most powerful influence in exciting nerve-force, and seems to have the most direct relation to it. If an electric current be made to pass *for a short distance only* along the trunk of a sensory nerve, or through its peripheral ramifications, it excites in the sensorium the peculiar sensations produced by ordinary impressions conveyed through that nerve; so again, if the current be transmitted for however short a space through a motor nerve, it excites contractions in the muscles which are supplied from its branches. It was formerly supposed that the electricity was the immediate cause of the changes thus induced in the sensorium or in the muscular apparatus; but it has been clearly proved that such is not the case, the passage of the current along a portion of the trunk being sufficient to excite the nerve-force in the remainder.—On the other hand, we have adequate proof that the force transmitted from the central ganglia to the muscles, is of the same nature with the preceding; for all the stimuli which excite sensations when applied to the trunks of the afferent nerves, excite motions when applied to the trunks of the efferent. This force seems to be developed by changes which take place in the vesicular matter of those ganglia (§§ 357—362); but the stimulus to that development may be of two very different kinds. For, on the one hand, the 'motor impulse' (as, for the sake of convenience, it may be designated) may be excited by a change originating in any part of the body, and transmitted to the ganglion through the afferent nerves; as in 'reflex' actions of various kinds. But, on the other, it may be called forth by an agency purely mental, which acts directly upon the vesicular matter of the ganglion, producing movements whose source is thus not peripheral, but central. And in states of peculiar functional activity of the nervous centres (such as that produced in the spinal cord by the administration of strychnine), it would appear as if motor impulses originate spontaneously, just like certain muscular contractions (§ 328); how far this must be accounted a normal *modus operandi*, however, is yet uncertain.

354. The influence of excitants repeatedly and powerfully applied to the Nervous tissue, is undoubtedly (as in the case of Muscle) to weaken, and at last to exhaust, its power of responding to them; this is seen alike in experimental researches, and in the ordinary course of vital action (§ 360). The excitability thus exhausted, can only be regained by an interval of repose, during which the nutritive operations may restore the tissue to its pristine integrity, and thus prepare it for renewed activity.—On the other hand, the moderate and regular excitation of Nervous activity, with due intervals of repose, is favourable to its nutrition; and this is especially to be noticed in the case of the Brain, an increased development of which, especially in young subjects, is continually to be noticed as consequent upon the continuance of a state of high functional activity. It seems probable that this augmentation is principally due, as in the case of Muscle, to the increased afflux of blood to the organ, which its functional activity induces. That the interruption of that activity not only suspends nutrition, but rapidly induces degenerative change, has been already shown (§ 347).

355. Of the conditions on which the functional activity of the Nervous system is dependent, the first is, of course, the integrity of its

own structure; thus, an interruption in any part of the 'nervous circle' will prevent the manifestation of its peculiar endowments. But, however perfect and complete its condition, no action can take place in it without a supply of *oxygenated blood;* which is more immediately necessary for the maintenance of the Nervous power, than it is for that of any other tissue whatever. That this supply is not so essential, however, to the *conduction* of impressions, as it is to their *reception* and *reflexion*, would appear alike from the difference between the amounts of blood transmitted to the *trunks* of the nerves in their course, and to their *peripheral* and *central* terminations; and from the different effects of the suspension of the circulation upon each. For the nerve-trunks are not peculiarly vascular; and retain their power of transmission for some time after the movement of the blood has ceased. On the other hand, both the nervous centres and the organs of sense receive an enormous supply of blood; and the effects of its interruption are immediately manifested in the most striking manner. Thus, if the circulation through the Brain be suspended but for an instant, insensibility and loss of voluntary power supervene, and continue until it is restored; as was shown in the following experiment by Sir A. Cooper. After having tied both carotid arteries in a dog, he compressed the Vertebral trunks; and immediate insensibility came on, the animal at the same time falling powerless. But convulsive movements occurred at the same time; showing that the functions of the spinal cord were not suspended, but only deranged. As soon as the blood was re-admitted to the brain, the animal recovered its consciousness and voluntary power, and stood on its legs again; the convulsive movements ceasing at the same time.*—In Syncope, moreover, the circulation through the Spinal cord is weakened, by the failure of the heart's action, to the same extent as the flow of blood through the Brain; and a general cessation, not merely of muscular movement, but of all power of exciting it, is the immediate result. No sooner, however, is the circulation fully re-established, than the power of the Nervous centres is restored.—Again, the influence of diminished circulation at the origins of the afferent nerves, is shown in the deficient impressibility of these nerves at the part affected. Thus, if the movement of blood through the capillaries of a limb be stagnated (whether by pressure on the arterial trunks, by cold, or by any other cause), the check is at once made apparent by the numbness of the surface; and a complete stagnation produces complete insensibility. The power of receiving impressions which excite reflex movements, is diminished in the same degree.

356. On the other hand it is found, that increased circulation through the same parts is attended with an exaltation of their function. This is particularly noticed in those affections of the brain and spinal cord, closely bordering on inflammation, to which the terms *active congestion* and *determination of blood* have been applied. We have, in such cases, extreme acuteness of sensation, excessive activity of the mental functions, or violent excitement of the motor powers; according (it would seem) to the particular division of the nervous centres most affected.—Again, we find that an increase in the circulation through any organ from which afferent

* "Guy's Hospital Reports," vol. i.

nerves arise, increases their readiness to receive impressions; thus the sensibility of the genital organs of animals during the period of heat, and of those of man in a state of venereal excitement, are greatly augmented; and the tendency of impressions made upon them to excite reflex movements, is similarly exalted.

357. The due activity of the Nervous System is not merely dependent upon a constant and ample supply of Blood; but it requires that this blood should be in a state of extreme purity, and more especially that it should contain a due supply of oxygen, and should be depurated of its carbonic acid, and of other products of the decomposition of the body. The final cessation of nervous power, in death by Asphyxia, is partly due (as will be shown hereafter, CHAP. X., SECT. 3), to a positive deficiency in the supply of blood; but the obtuseness of sensibility which gradually increases until a state of unconsciousness comes on, may be clearly traced in the first instance to the deficient aeration of the blood, which is gradually deprived of its oxygen, and more and more charged with carbonic acid. Corresponding but less severe symptoms occur, when the excretion of carbonic acid is not checked, but only slightly impeded, provided the impediment be in operation for a sufficient length of time, as in the case of an ill-ventilated apartment; an indisposition to mental exertion, a deficiency of muscular power, and an obtuseness of the intellectual and moral faculties, being the general result.—The retention of other excrementitious products in the Blood is not less injurious, though its operation is less rapid. Thus when the elimination of Biliary matter is prevented, so that the blood becomes unduly charged with its components, a great deficiency of Nervous power is manifested; the general sensibility being rendered obtuse, the mental operations becoming torpid, and the motor energy enfeebled; and this state may become more and more intense, with the increase of the accumulation, until, as in Asphyxia, the entire functional activity of the Nervous system becomes extinct. The effect of the retention of the materials of the Urinary excretion is not very dissimilar; but with the gradually-deepening Coma, there are usually (as in Asphyxia) convulsive movements.—The influence of various poisons introduced into the blood *ab extra*, upon the functional activity of the Nervous system, exhibits in a very marked manner the extreme importance of the purity of the circulating fluid, to the normal performance of the duties of this most important apparatus. Thus we find the action of one class of poisons to commence with the disturbance of the *mental* powers; the control exercised by the will over the course of thought is weakened, incoherence succeeds to regularity, passion takes the place of calmness, and the state at last becomes one of maniacal delirium. Another class acts primarily on the *sensorial* powers; the consciousness of external impressions being first rendered obtuse, and then entirely destroyed; and all the movements which are ordinarily excited or guided by it, being consequently checked. And a third class operates especially upon the *motor* portion of the nervous apparatus; inducing an extraordinary degree of excitability in that portion of the central organs which responds to the action of stimuli; or, on the other hand, diminishing the normal excitability, to such a degree that not only the ordinary stimuli, by excitants of unusual potency, occasion no response.—We shall hereafter see (CHAP. XIV., SECT. 7) that there is a very strong probability, that a large

proportion of the disordered actions of the Nervous System depend upon the presence of poisonous matters in the blood, which have not been introduced from without, but have been generated within the system itself.

358. All that we know respecting the conditions on which the production of Nervous Force is dependent, supports the belief that its evolution involves *a change of composition* in the Nervous matter; this change essentially consisting in the cessation of its existence as a living tissue, and in the combination of oxygen with its constituents; so that, in their restoration to the condition of inorganic matter, the Vital force, which was previously operative in the growth and development of the tissue, is set free under this peculiar form. It may serve to render this doctrine more intelligible, if we again refer to the analogy of the Galvanic battery; in which the change in the condition of the zinc (or other oxidizable metal), which ceases to exist as such, and which enters into new chemical combinations, is the condition of the evolution of the electric force.—The chief grounds for this doctrine will now be enumerated.

359. In the first place, the dependence of Nervous energy upon the constant circulation of Blood through the tissue, is much more close and immediate, than can be accounted-for on the idea that the relation is one of mere nutrition or development. On the contrary, where these last changes are taking place most actively, we often find rather a disposition to stagnation of the current, to give time for the elaboration of the nutrient materials that are to be withdrawn from it; and in no case does the process so instantaneously cease, when the flow is suspended. From this it would appear, that a reaction takes place between the elements of the Nervous tissue and some material supplied by the Blood, which is much more rapid in its character than the process of cell-development, and which is essentially concerned in the production and maintenance of the nervous activity. That the material supplied by the blood for this purpose is Oxygen, would appear from a variety of considerations. A general survey of the Animal kingdom shows, that oxygen is essential to the maintenance of *animal* life, as distinct from *vegetative;* and a more particular comparison of different tribes demonstrates most unequivocally, that the consumption of oxygen is in direct relation to the development of the animal powers in each.* The effects of a suspension of the oxygenating process (§ 357) completely harmonize with these facts.

360. Further, in proof that the activity of the Nervous system is immediately dependent, not upon a process of development or nutrition, but upon one of disintegration or destruction, it may be urged, that it is impossible for this state of activity to be maintained in a large portion of it, without an interval of repose, which we know to be favourable to the vegetative or reparative processes. It is true that there are certain portions of it, particularly those that put in action the respiratory muscles, which are in a state of unceasing though moderate activity; and in these, the constant nutrition is sufficient to repair the effects of the constant decay. But those parts which operate in a more powerful and energetic manner, and which are therefore more rapidly disintegrated when in action, need a season of rest for their reparation. Hence the sense of fatigue which is

* See "Princ. of Phys., Gen. and Comp.," CHAP. XIII.

xperienced, when the Mind has been long acting through its instrument, he Brain;* and the irresistible tendency to sleep, which usually superenes after any unusual exertion of this kind. In the healthy state of he body, when the exercise of the Nervous system by day does not exceed hat which the repose of the night may compensate, the nutritive operaons maintain it in a condition which fits it for constant moderate exercise; ut unusual demands upon its activity,—whether by long-continued and evere exercise of the intellect, by excitement of the emotions, or by the ombination of both, in that state of *anxiety* which the circumstances of nan's condition too frequently induce,—occasion an unusual 'waste,' and equire a prolonged repose and uninterrupted nutrition, for the complete estoration of its powers. There can be no doubt that (from causes which re not known) the amount of Sleep required by different persons, for the naintenance of a healthy condition of the nervous system, varies conderably; some being able to dispense with it, to a degree which would e exceedingly injurious to other individuals, who do not surpass them in nental activity. Where a prolonged exertion of the mind has been made, nd the natural tendency to sleep has been habitually resisted by a strong fort of the will, injurious results are sure to follow. The bodily health reaks down; and too frequently the mind itself is permanently enfeebled. is obvious that the Nutrition of the nervous system becomes completely eranged; and that the tissue is no longer formed in a manner requisite r the discharge of its healthy functions. The same may be said of the ate of Mania; in which there is, for a time, an extraordinary degree of tivity (though manifested in an irregular manner) of the cerebral funcons, and an absence of disposition to sleep. Such a state may continue r some weeks; but the subsequent exhaustion of nervous power is prortioned to the duration of the excitement, and frequent attacks of mania most invariably subside at last into Imbecility.

361. Additional evidence for the belief that the functional activity of e Nervous tissue involves disintegration of its tissue by the agency of xygen, is found in the increase of *alkaline phosphates* in the urine, when ere has been any unusual demand upon the nervous power. No others the soft tissues contain any large amount of phosphorus; and the arked increase in these deposits, which has been continually observed to company long-continued *wear* of mind (whether by intellectual exertion, by the excitement of the feelings), and which follows any temporary ain upon its powers, may fairly be attributed to this cause. The most tisfactory proof is to be found in cases in which there is a periodical mand upon the mental powers; as, for example, among Clergymen, in e preparation for and discharge of their Sunday duties. This, when e demand for mental exertion is severe, and especially when there is t state of excitability of the nervous system which is frequently coexist with a diminution of its vigour, is found to be very commonly followed the appearance of a large quantity of the alkaline phosphates in the ne. And in cases, in which constant and severe intellectual exertion s impaired the nutrition of the brain, and has consequently weakened mental power, it is found that any premature attempt to renew the

Of the sense of fatigue induced by continued muscular exertion, it is difficult to say how h is attributable to the state of the Muscles themselves; it is better, therefore, to base this ement upon cases in which the activity is purely Nervous.

activity of its exercise, causes the re-appearance of the excessive phosphatic discharge, indicative of an undue 'waste' of nervous matter.* Further, it has been shown by Dr. Bence Jones,† that acute affections of nervous substance, both organic and functional, are generally attended with an increase in the phosphatic salts of the urine; the amount of phosphates, in acute inflammation of the brain, seeming to be proportional to the intensity of the inflammation, and in various forms of disordered action (delirium tremens, however, constituting a marked exception), to the degree of mental disturbance.—There are, however, many other sources of increase in the phosphatic components of the urine; and hence it is only when these are excluded or allowed-for, that the increase attributable to 'waste' of Nervous tissue can be estimated.‡

362. The rapid disintegration of Nervous tissue, when in a state of functional activity, is further indicated by the demand for aliment which this creates; for every one who has been accustomed to habits of sustained mental exertion, must be conscious that, where the general health is good, the appetite for food is no less engendered by such labour, than it is by the exertion of the muscular powers. Further, as already pointed out, there are appearances in the Nervous tissue itself, which indicate that nutritive changes are continually in progress in its substance (§ 346); and the rapidity with which it undergoes alteration when its functional operations are suspended, is an additional indication of the activity of the changes of composition (of however different a nature such may be) which those operations involve.

363. In all that has been said on this subject, reference has been especially made to the 'vesicular' element of the Nervous Centres; for in regard to the 'fibrous' component of the nerve-trunks, which is a mere *conductor* of the force generated there, the evidence of continual change is not of a kind to justify any such assumption. In fact, there would appear to be strong reasons for believing, that the amount of 'waste' which it undergoes in the discharge of this office, is comparatively trifling (§ 355).

364. Of the actual nature of the changes, by which impressions are received upon the peripheral origins of the afferent nerves, or are communicated to the central origins of the motor, and by which they are conducted along each to their opposite extremities, Physiologists have no certain knowledge. That they are Electrical in their character, has been,

* The Author has known more than one case of this kind, occurring among young men whose anxiety for distinction had induced them to go through an excessive amount of intellectual labour during their Student-life, and who found themselves forced to pay the penalty of that excess, in a subsequent prolonged abstinence from all mental occupation involving the slightest degree of effort.

† "Philosophical Transactions," 1846.

‡ Thus, a considerable amount of phosphates, alkaline as well as earthy, passes into the urine directly from the food, without ever becoming part of the living tissue; so that, if food be withheld, there is an immediate diminution in the quantity which the urinary secretion contains,—a consideration of special importance in studying the influence of acute diseases, in which the quantity of aliment taken is very small. So, again, there are various disordered states of the digestive system, in which there is an excess of phosphates in the urine, without any coincident indication of excessive 'waste' of nervous tissue. Moreover, the *deposit* of phosphatic salts is by no means an adequate indication of their presence in excess; since their insolubility may depend upon conditions altogether different.—See especially Dr. Golding Bird's treatise on "Urinary Deposits," CHAP. X.

and still continues to be, a favourite theory with some; and the idea seems to derive support from the marked degree in which Electricity, transmitted along the Nervous trunks, can excite the changes to which those nerves are ordinarily subservient. Thus, a feeble galvanic current, transmitted along the motor nerves of an animal recently killed, will call the muscles supplied by it into contraction; whilst, on the other hand, a similar current transmitted along an afferent nerve, shall excite reflex movements through its ganglionic centre. Further, if the current be transmitted along an afferent nerve, in a living animal, it will excite sensations which are referred to the part whence the nerve arises; and, as will be shown hereafter (CHAP. XV., SECT. 1), Electricity is capable of thus producing sensations of a *special* kind, as well as those of a *general* nature. Moreover, in the instantaneousness of the transmission of Nervous agency from one part of the system to another, there is more analogy to Electricity, than to any other known force. But these and similar arguments do not prove the *identity* of Nervous agency with Electricity; since the effects of the former may be imitated to a certain extent, not merely by Electricity, but by mechanical and chemical stimulation of various kinds. —Further, there are powerful arguments *against* such a supposition, the validity of which cannot be easily set aside. All attempts to prove the existence of an Electric current, in a Nervous trunk that is actually engaged in conveying motor influence, have completely failed, though made with the greatest precaution. Thus, Prof. Matteucci having experimented upon the very large crural nerve of a Horse, which was caused, by stimulating its roots, to throw the muscles of the leg into violent contraction, nevertheless found that, although he used instruments of such delicacy as to be capable of detecting an infinitesimally-small disturbance of the electric equilibrium, no such disturbance was evident.* Further, it is well known that the conducting power of the nerves is destroyed, not merely by dividing the trunk, but also by putting a ligature round it; which last operation does not diminish its powers as a conductor of Electricity. Moreover, the various fibrils are not as completely insulated from each other in regard to Electricity, as we know them to be with respect to nervous agency; for the first of these forces, when transmitted along a nervous trunk, cannot be restricted to any fibre or fasciculus of fibres, but spreads through the entire trunk, and even to the neighbouring parts in which it is imbedded; whilst the latter is continually restricted to a small portion of the trunk, as is manifested by its results. Again, if a small piece of a nervous trunk be cut out, and be replaced by an electric conductor, electricity will still pass along the nerve; but no nervous force, excited by stimulus above the section, will be propagated through the conductor to the parts below. And lastly, the conducting power of Nerve for Electricity is stated by Matteucci to be not more than one-fourth of that of Muscle; whilst Messrs. Todd and Bowman give it as the result of their experiments, that both Nerve and Muscle are *infinitely worse* conductors than copper; their power of conduction not ranking above that of water holding in solution a small quantity of saline matter.

* See on this subject Prof. Matteucci's various Memoirs in the "Philosophical Transactions;" and his "Lectures on the Physical Phenomena of Living Beings" (translated by Dr. Pereira), p. 284.

365. We shall probably form the most correct idea of the relation which subsists between Electricity and Nervous power, by regarding it as of the same kind as that which subsists between Electricity and Heat or Magnetism. For as a current of Electricity passed through a small wire generates Heat, and Heat applied to a particular combination of metals generates Electricity,—or as an Electric current passed round a bar of iron renders it Magnetic, whilst conversely the Magnetic force will generate the Electric,—so do we find that a current of Electricity, passed through a small portion of a motor or sensory nerve, will excite the Nervous force in the remainder; whilst there seems reason, from the phenomena of the Electric Fish, to consider that Nervous force may in its turn generate Electricity. Hence we may regard them as closely *correlated*, though not identical;* and this idea of 'correlation' we seem justified in extending to those other Physical agencies, which have been shown to be capable of exciting Nervous force; namely, Heat, Light, Chemical Affinity, and Mechanical Motion. For there is adequate ground for the belief, that either of the three former may be excited by Nervous agency, although its most obvious manifestation is the production of movement; and that thus, as each of these agencies is capable of developing Nerve-force, and of being in its turn developed by it, their relationship to it is no less intimate than that which they bear to each other, although a more special apparatus is required for its instrumental operation. And considering that Nerve-force is the highest of all the manifestations of Vital power, alike in its general control over the bodily fabric, and in its relations to the functions of the Mind, it is strikingly confirmatory of the views formerly expressed (CHAP. III., SECT. 2), to find that its connection with the Physical forces is so peculiarly intimate.

*a.* Although for the sake of convenience, Electricity and Nervous power are spoken of, here and elsewhere, as actual *entities* or *agents*, travelling in currents along the wires or cords that conduct them, it must not be forgotten that the present tendency of scientific inquiry leads us to abandon such an idea, in the former case at least; what is commonly termed the *transmission* of electricity being the result of a *molecular change*, instantaneously occurring along the whole length of the conducting body, in virtue of a disturbance in the *polar* arrangement of its particles, at one extremity, which causes a similar disturbance to manifest itself at the other. Thus, if

$$ab \quad ab \quad ab \quad ab \quad ab \quad ab \quad ab \quad ab$$

represent the arrangement of the particles, in the condition of equilibrium or quiescence, and this condition be disturbed at one extremity, by the operation of a new attraction upon the first particle $a$, a new arrangement will instantaneously take place throughout: this may be represented by

$$a \quad ba \quad ba \quad ba \quad ba \quad ba \quad ba \quad ba \quad b,$$

which shows $b$ in a free state at the opposite end, ready to exert its influence upon anything submitted to it. It is probable that in this respect there is an analogy between the Nervous and Electrical forces; and that, instead of speaking of the "transmission of nervous influence" along a nerve, we should describe the change as the production of a "polar state" in the nervous trunk; as was first pointed out by Messrs. Todd and Bowman ("Physiological Anatomy," vol. i. p. 240).

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* See Prof. Grove's Treatise "On the Correlation of the Physical Forces;" and the Author's Memoir "On the Mutual Relations of the Vital and Physical Forces," in the "Philosophical Transactions" for 1850.—This doctrine has been formally adopted by Prof. Matteucci, in his Eighth Series of 'Electro-Physiological Researches,' published in the "Philosophical Transactions" for 1850, p. 296.

# CHAPTER VI.

## GENERAL VIEWS OF THE FUNCTIONS OF THE HUMAN BODY.

### 1. *Of the Mutual Dependence of its Vital Actions.*

366. By the study of the various forms of Elementary Tissue of which the Human fabric is made up, we are led to the very same conclusion with that which we draw from the observation of the simplest forms of organized being, or from the scrutiny into the earliest condition of the most complex;—namely, that *the simple Cell may be regarded as the type of Organization; and that on its actions rest our fundamental idea of Life.* Between the humblest Plant, and the embryonic Human organism, there is originally no perceptible difference; they may be said to have a common starting-point; and the subsequent difference of their course consists essentially in this,—that the successive generations of cells, which are the descendants of the former, are *all similar to it and to each other*, each cell being capable of maintaining an *independent* existence; whilst the subsequent generations which originate from the latter, progressively become more and more *dissimilar to each other*, and more and more *mutually dependent;* so that whenever it is thrown entirely upon its own resources, the integrity of the whole fabric becomes essential to the continued life of any individual cell. Every individual part, however, even in the most complex and highly-organized fabric, has its own capacity of development; and the properties which it possesses are the result of its exercise. But instead of the power of cell-growth being exerted, as in the Plant, upon the inorganic elements around, it can only be put in action, in the Animal, upon certain peculiar compounds, having the same chemical composition with its own substance; and it is for the reception of these, for their preparation, and for their maintenance in the requisite state of purity, that a large part of the fabric of the Animal is destined. But if we could imagine its several tissues to be supplied with nutriment in any other manner, and maintained in other respects in their normal circumstances (as regards warmth, air, &c.), we have every reason to believe, that their independent vitality would manifest itself by their continued development, and by the regular exhibition of their ordinary properties. An approach to this condition is made, in the experiment of entirely detaching a limb from the body, but keeping up the circulation of blood through it, by means of tubes connecting its main artery and vein with those of the stump. Notwithstanding the prejudicial effect of such severe injuries, the persistence of the muscular irritability in the separated part (§ 322), is a sufficient proof of the continuance of the normal actions of nutrition, although of course in a diminished degree. And the occasional reunion of a member which has been entirely separated, when decomposing changes have not yet commenced in it, most clearly shows, that nothing but the restoration of its current of blood is requisite for the preservation of its vitality, and that its powers of

growth and renovation are inherent in itself, only requiring a due supply of the nutrient material, with certain other concurrent conditions.

367. In every living structure of a complex nature, therefore, whilst we witness a great variety of actions, resulting from the exercise of the different powers of its several component parts, we at the same time perceive that there is a certain harmony or co-ordination amongst them all, whereby they are all made to concur in the maintenance of the Life of the organism as a whole. And if we take a general survey of them, with reference to their mutual relations to each other, we shall perceive that they may be associated into groups; each consisting of a set of actions, which, though different in themselves, concur in effecting some positive and determinate purpose. These groups of actions are termed *Functions.* —Thus, one of the most universal of all the changes necessary to the continued existence of a living being, is the exposure of its nutritious fluid to the air; by the action of which upon it, certain alterations are effected. For the performance of this aeration, simple as the change appears, many provisions are required. In the first place, there must be an aerating surface, consisting of a thin membrane, permeable to gases; on the one side of which the blood may be spread out, whilst the air is in contact with the other. Then there must be a provision for continually renewing the blood which is brought to this surface; in order that the whole mass of fluid may be equally benefited by the process. And, in like manner, the stratum of air must also be renewed, as frequently as its constituents have undergone any essential change. We include, therefore, in speaking of the 'function of respiration,' not only the actual aerating process, but also the various changes which are necessary to carry this into effect, and which obviously have it for their ultimate purpose.

368. On further examining and comparing these Functions, we find that they are themselves capable of some degree of classification. Indeed the distinction between the groups into which they may be arranged, is one of essential importance in Animal Physiology. If we contemplate the history of the Life of a Plant, we perceive that it grows from a germ to a fabric of sometimes gigantic size,—generates a large quantity of organized structure, as well as many organic compounds, which form the products of secretion, but which do not undergo organization,—and multiplies its species, by the production of germs similar to that from which it originated;—but that it performs all these complex operations, without (so far as we can perceive) either feeling or thinking, without consciousness or will. All the functions of which its Life is composed, are, therefore, grouped together under the general designation of Functions of *Organic* or *Vegetative* life; and they are subdivided into those concerned in the development and maintenance of the structure of the individual, which are termed functions of *Nutrition,* and those to which the *Reproduction* of the species is due. —The great feature of the Nutritive operations in the Plant, is their *constructive* character. They seem as if destined merely for the building-up and extension of the fabric; and to this extension there seems in some cases to be no determinate limit. But it is very important to remark, that the growth of the more *permanent* parts of the structure is only attained by the continual development, decay, and renewal of parts, whose existence is *temporary.* No fact is better established in Vegetable Physiology, than the dependence of the formation of

wood upon the action of the leaves. It is in their cells that those important changes are effected in the sap, by which it is changed, from a crude watery fluid containing very little solid matter, to a viscid substance including a great variety of organic compounds, destined for the nutrition of the various tissues. The 'fall of the leaf' results merely from the death and decay of its tissue; as is evident from the fact, that, for some time previously, its regular functions cease, and that, instead of a fixation of carbon from the atmosphere, there is a liberation of carbonic acid (a result of their decomposition) in large amount.* Now this process takes place no less in 'evergreens' than in 'deciduous' trees; the only difference being, that the leaves in the latter are all cast off and renewed together, whilst in the former they are continually being shed and replaced, a few at a time. It appears as if the nutritious fluid of the higher Plants can *only* be prepared by the agency of cells whose duration is brief; for we have no instance in which the tissue concerned in its elaboration possesses more than a very limited term of existence. But by its active vital operations, it produces a fluid adapted for the nutrition of parts which are of a much more solid and permanent character, and which undergo little change of any kind subsequently to their complete development; this want of tendency to decay being the result of the very same peculiarity of constitution, as that which renders them unfit to participate in the proper vital phenomena of the organism (§ 114). Thus the final cause or purpose of all the Nutritive functions of the Plant, so far as the *individual* is concerned, is to produce an indefinite extension of the dense, woody, almost inert, and permanent portions of the fabric, by the continued development, decay, and renewal of the soft, active, and transitory cellular parenchyma. —The Nutritive functions, however, also supply the materials for the continuance of the *race*, by the generation of new individuals; since a new germ cannot be formed, any more than the parent structure can be extended, without organizable materials, prepared by the assimilating process, and supplied to the parts where active changes are going on.

369. On analysing the operations which take place in the Animal body, we find that a large number of them are of essentially the same character with the foregoing, and differ only in the conditions under which they are performed; so that we may, in fact, readily separate the *Organic* functions, which are directly concerned in the development and maintenance of the fabric, from the *Animal* functions, which render the individual conscious of external impressions, and capable of executing spontaneous movements. The relative development of the organs destined to these two purposes, differs considerably in the several groups of Animals. The life of a Zoophyte is upon the whole much more 'vegetative' than 'animal;' and we perceive in it, not merely the very feeble development of those powers which are peculiar to the Animal kingdom, but also that tendency to indefinite extension which is characteristic of the Plant. In the Insect we have the opposite extreme; the most active powers of motion, and sensations of which some (at least) are very acute, coexisting with a low development of the organs of nutrition. In Man and the higher classes generally, we have less active powers of locomotion, but a much greater variety of Animal faculties; and the instruments of the

* See "Princ. of Phys., Gen. and Comp.," §§ 120, 494, 554.

Organic or nutritive operations attain their highest development, and their greatest degree of mutual dependence. We see in the fabric of all beings, in which the Animal powers are much developed, an almost entire want of that tendency to indefinite extension, which is so characteristic of the Plant; and when the large amount of food consumed by them is considered, the question naturally arises, to what purpose this food is applied, and what is the necessity for the continued activity of the Organic functions, when once the fabric has attained the limit of its development.

370. The answer to this question lies in the fact, that the exercise of the Animal functions is essentially destructive of their instruments; every operation of the Nervous and Muscular systems involving, as its necessary condition, a disintegration of a certain part of their tissues; so that the duration of the existence of those tissues varies inversely to the use that is made of them, being less as their functional activity is greater. Hence, when an Animal is very inactive, it requires but little nutrition; if in moderate activity, there is a moderate demand for food; but if its Nervo-muscular energy be frequently and powerfully aroused, the supply must be increased, in order to maintain the vigour of the system.—We are not to measure the activity of the Nervous system, however, like that of the Muscular, only by the amount of *movement* to which it gives origin. For there is equal evidence, that the demand for blood in the Brain, the amount of nutrition it receives, and the degree of disintegration it undergoes, are proportional likewise to the energy of the purely *psychical* operations; so that the vigorous exercise of the intellectual powers, or a long-continued state of agitation of the feelings, produces as great a 'waste' of Nervous matter, as is occasioned by active bodily exercise. From this and other considerations, we are almost irresistibly led to the belief, that every act of Mind is inseparably connected, in our present state of being, with material changes in the Nervous System; a doctrine not in the least inconsistent with the belief in the separate immaterial existence of the Mind itself, nor with the expectation of a future state in which the communion of Mind with Mind shall be more direct and unfettered.

371. Thus in the Animal fabric, among the higher classes at least, the function or purpose of the organs of Vegetative life is not so much the extension of the fabric, for this has certain definite limits, as *the maintenance of its integrity, by the reparation of the destructive effects of the exercise of the purely Animal powers.* By the operations of Digestion, Assimilation, and Circulation, the nutritive materials are prepared and conveyed to the points where they are required; the Circulation of Blood also serves to transmit oxygen, which is introduced by the Respiratory process; and it has further for its office to convey away the products of that decomposition of the Muscular and Nervous tissues, which results from their functional activity, these products being destined to be separated by the Respiratory and other Excreting operations. In the performance of the Organic functions of Animals, as in those of Plants, there is a continual new production, decay, exuviation, and renewal, of the cells by whose instrumentality they are effected; which altogether effect a change not less complete than that of the leaves in Plants. But it takes place in the penetralia of the system, in such a manner as to elude observation, except that of the most scrutinising kind; and it has been in bringing

this into view, that the Microscope has rendered most essential service in Physiology.

372. The regular maintenance of the functions of Animal life is thus entirely dependent upon the due performance of the Nutritive operations; a consideration of great importance in practice, since a very large proportion of what are termed 'functional disorders' (of the Nervous system especially) are immediately dependent upon some abnormal condition of the Blood. But there also exists a connection of an entirely reverse kind, between the Organic and Animal functions; for the conditions of Animal existence render the former in great degree dependent on the latter. In the acquisition of food, for example, the Animal has to make use of its senses, its psychical faculties, and its power of locomotion, to obtain that which the Plant, from the different provision made for its support, can derive without any such assistance; moreover, the propulsion of the food along the alimentary canal of the former, requires a series of operations in which Muscular contractility is required, the Nervous and Muscular systems being together employed at the two extremes; and thus we see that the change in the conditions required for the ingestion of food by Animals, has rendered necessary the introduction of additional elements into the apparatus, to which nothing comparable was to be found in plants. Again in the function of respiration, as performed in Man and the higher animals, the Nervous and Muscular systems are alike involved; for the movements by which the air in the lungs is being continually renewed, are dependent upon the action of both; and those by which the blood is propelled through the respiratory organs, are chiefly occasioned by the contractility of a muscular organ, the heart. Such movements, however, as are thus immediately connected with the maintenance of the Organic functions, do not depend upon the *will*, and may even be performed without our *consciousness;* they can scarcely be regarded, therefore, as forming part of our proper Animal life; and the only essential difference which they present, from those which are occasionally performed by Plants (especially such as exhibit the transmission of the effect of a stimulus to some distance,—the folding of the leaves of the Mimosa, or the closure of the fly-trap of the Dionæa, for example), consists in the instrumentality through which they are performed,—this being in Animals a peculiar Nervous and Muscular apparatus, whilst in Plants it is only a modification of the ordinary structure.

373. From what has been said, then, it appears that all the functions of the Animal body are so completely bound up together, that none can be suspended without the cessation of the rest. The properties of all the tissues and organs are dependent upon their regular Nutrition, by a due supply of perfectly-elaborated blood; this cannot be effected, unless the functions of Circulation, Respiration, and Excretion, be performed with regularity,—the first being necessary to convey the supply of nutritious fluid, and the two latter to separate it from its impurities. The Respiration cannot be maintained, without the integrity of a certain part of the Nervo-muscular apparatus; and the due action of this, again, is dependent upon its regular nutrition. The materials necessary for the replacement of those which are continually being separated from the blood, can only be derived by the Absorption of ingested aliment; and this cannot

be accomplished, without the preliminary process of Digestion. The introduction of food into the stomach, again, is dependent, like the actions of Respiration, upon the operations of the muscular apparatus and of a part of the nervous centres; and the previous acquirement of food necessarily involves the purely Animal powers. Now it will serve to show the distinction between these powers, and those which are merely subservient to Organic life, if we advert to the case, which is of no unfrequent occurrence, of a Human being, deprived by some morbid condition of the brain, of all the powers of Animal life, sensation, thought, volition, &c.; and yet capable of maintaining a Vegetative existence, in which all the organic functions go on as usual,—that division of the nervous system which is concerned in the movements whereon some of them depend, not being yet affected by the morbid influence. It is evident that we can assign no definite limits to such a state, so long as the respiratory movements are sustained, and the necessary food is placed within reach of the grasp of the muscles that will convey it into the stomach: as a matter of fact, however, it is seldom of long continuance, since the disordered state of the brain is sure to extend itself, sooner or later, to the rest of the nervous system. This condition may be experimentally imitated, however, by the removal of the brain, in many of the lower animals, whose bodies will sustain life for many months after such a mutilation; but this can only take place, when that food is conveyed by external agency within the pharynx, which they would, if in their natural condition, have obtained for themselves. A similar experiment is sometimes made by Nature for the Physiologist, in the production of fœtuses, as well of the human as of other species, in which the brain is absent; these can breathe and suck and swallow, and perform all their organic functions; and there is no assignable limit to their existence, so long as they are duly supplied with food.* Hence we may learn the exact nature of the dependence of the Organic functions upon those of purely Animal life; and we perceive that, though less immediate than it is upon the simple excito-motor actions of the nervous and muscular systems, it is not less complete. On the other hand, the functions of Animal life are even more closely dependent upon the Nutritive actions, than are those of organic life in general; for many tissues will retain their several properties and their power of growth and extension, for a much longer period after a general interruption of the circulation, than will the Nervous structure; which is, indeed, instantaneously affected by a cessation of the due supply of blood, or by the depravation of its quality (§ 356).

## 2. *Functions of Vegetative Life.*

374. As a certain change of composition of the Organized fabric is a necessary condition of every manifestation of its Vital activity, it is

* A very remarkable case has been mentioned to the Author by his friend Mr. Wallis of Hull; the subject of which has never, from the time of his birth, exhibited any distinct indication of consciousness, and has yet, by sedulous care, been reared to the age of ten years. There is no appearance of any malformation about the Brain, and yet it must obviously be functionally inactive; for no movements have ever been witnessed, which seem to proceed from any higher centre than the Medulla Oblongata. Even in the administration of nourishment, it is necessary that the food should be carried back into the pharynx, so that it may be grasped by the reflex action of its constrictors.

obviously requisite that a provision should exist for the replacement, by new matter, of all those particles, which, having lost their vital endowments, are in process of return to the condition of inorganic matter. And hence, of course, every increase in the activity of the Animal functions becomes a source of augmented demand for nourishment; provided, at least, that such increase does not go to the extent of exhausting the vital energies, and thus of preventing the due performance of the Nutritive functions. A constant supply of Aliment is therefore needed for the *maintenance* of the body, after it has arrived at its full development. The effects of the process of waste and decay, uncompensated by that of renovation, are seen in starvation and in diseases of exhaustion (§ 416); in which there is a gradual diminution in the bulk of nearly all the tissues of the body, so that, before death supervenes, the total reduction in weight is very considerable.—But in the *growing* state of the organism there is, of course, an additional demand for Aliment, to supply the materials for the extension which is continually taking place in it. This, however, does not make so great a difference as it might appear to do, in the supply of food which is required. For if the absolute *addition* which is made by growth to the body in any given time, be compared with the amount of *change of composition* which takes place in the same period,—the latter being judged-of by the quantity of food consumed, and by the amount of excrementitious matter which passes off by the lungs, liver, kidneys, skin, &c.—it will be found to bear but a very small proportion to it. The fact is rather, that, during the whole period of growth, there is (so to speak) a continual re-modelling of the entire fabric; the life of each part being brief, in order that its renovation may be effected on a somewhat different scale (§§ 130, 131). And thus it happens that children require a much larger amount of food in proportion to their bulk, than that which suffices for adults. On the other hand, in old persons, the life of each part is comparatively slow; its vital operations are deficient in activity; and the processes of waste and the demand for food are proportionally retarded (§ 133).

375. But another and most important source of demand for food, in Man and warm-blooded animals generally, arises out of the requirements of the *combustive* process, whereby the Heat of the body is maintained. This demand will vary, *cæteris paribus*, with the amount of heat to be generated, which bears a direct proportion to the depression of the external temperature, the standard of the body itself being fixed. Hence external Cold comes to be a source of demand for food; whilst artificial warmth may be made to take the place of the nourishment otherwise required for this purpose; as was shown by the remarkable experiments of Chossat hereafter to be referred-to (CHAPS. VII. and XIII). —But if the amount of exercise taken be very considerable, especially in warm climates, where the demand for the production of Heat is reduced to its minimum, a sufficient amount of *pabulum* for the respiratory process may be provided by the disintegration of the nervo-muscular apparatus, without any special supply being required.

376. The demand for food is increased by any cause which creates an unusual drain or waste in the system. Thus an extensive suppurating action can be sustained only by a large supply of highly nutritious food. The mother, who has to furnish the daily supply of milk, which consti-

tutes the sole support of her offspring, needs an unusual sustenance for this purpose. And there are states of the system, in which the solid tissues seem to possess an abnormal tendency to decomposition, and in which an increased supply of aliment is therefore required. This is the case, for example, in Diabetes; one of the first symptoms of which disease is the craving appetite, that seems as if it would be never satisfied. And there can be no doubt that, putting aside all the other circumstances which have been alluded to, there is much difference amongst individuals, in regard to the rapidity of the changes which their organism undergoes, and the amount of food consequently required for its maintenance.

377. The want of solid aliment is made known by the feeling of Hunger; and that of liquids, by the feeling of Thirst. These feelings, as will be shown hereafter (CHAP. VII., SECT. 2), are but secondarily dependent upon the state of the stomach; and may be considered, in the state of health, as tolerably faithful indications of the wants of the body at large. They become the stimulants to mental operations, having for their object the gratification of the desire by the acquisition of food. In the state of Infancy, the actions which they prompt are obviously automatic; that is, they are performed in direct respondence to the appropriate stimulus, and do not involve any idea of purpose or object on the part of the being which executes them. But in all succeeding periods of life, they are purely *voluntary;* being performed with a designed or purposive adaptation of *means,* to *ends* which are clearly before the consciousness.—The reception of food into the mouth, and its preparation by the acts of mastication and insalivation, would seem rather to belong to the *consensual* or 'sensori-motor' class of movements; being performed quite independently of the will, whenever that power is in abeyance, or is differently directed. By these movements, the aliment is brought within reach of the pharyngeal muscles, whose contraction cannot be effected by the will, but is purely *reflex,* or 'excito-motor,' resulting merely from the conveyance to the Medulla Oblongata of the impression made upon the fauces by the contact of the substance swallowed, and from the reflexion of an influence excited by that impression, back to the muscles. By these it is propelled down the œsophagus; and, after their action has ceased, it is taken up (as it were) by the muscular coat of the œsophagus itself, and is conveyed into the stomach. How far the movements of the lower parts of the œsophagus and of the stomach are in Man dependent upon reflex action, is uncertain; the facts which have been ascertained on this point, by experiment on animals, will be detailed in their proper place (§§ 428, 430).

378. In the Stomach, the food, certain components of which have been already altered by the chemical action of the saliva, is brought under the influence of the gastric secretion; the chemical action of which, aided by the constantly-elevated temperature of the interior of the body, and by the continual agitation effected by the contractions of the parietes of the organ, effects a more or less complete reduction of it. Some of its nutritive components, being actually *dissolved* by the gastric juice, are thus prepared for immediate absorption; but others require the admixture of the biliary and pancreatic secretions, whereby various changes are effected in their condition, which prepare them also for reception into the circulating system. The nutritious portion being gradually taken

up by the Blood-vessels and by the Absorbent vessels (or Lacteals), which are distributed on the walls of the alimentary canal, the indigestible residue is propelled along the intestinal tube by the simple contractility of its walls, undergoing at the same time some further change, by which the nutritive materials are still more completely extracted from it. And at last, the excrementitious matter,—consisting not only of the insoluble portion of the food taken into the stomach, but also of part of the secretion of the liver, and of that of the mucous surface of the intestines and of their glandulæ,—is voided from the opposite extremity of the canal, by a muscular exertion, which is partly reflex, like that of deglutition, but is partly voluntary, especially (as it would appear) in Man. The whole of this series of operations, by which the nutritive materials are prepared for being absorbed, may be considered as constituting the function of *Digestion.*

379. The introduction of the nutritive materials thus prepared, into the vessels which convey them to the tissues, constitutes the function of *Absorption.* But these materials undergo important changes in their progress towards the centre of the circulation, whereby they are brought more nearly to the condition of true Blood; and these changes are designated by the term *Assimilation.*—There seems no doubt that fluid containing saline, albuminous, or other matters in a state of complete solution, may be absorbed by the Blood-vessels with which the mucous membrane of the alimentary canal is so copiously supplied; and this simple process of imbibition probably takes place according to the physical laws of Endosmose. But the selection and absorption of some of the nutritive materials appear to be performed, not by *vessels,* but by the specific vital endowments of *cells* (§ 460), which subsequently yield up their contents to the Lacteals. The fluid thus absorbed, which now receives the name of Chyle, is propelled through the Lacteals by the contractility of their walls; aided in part, perhaps, by a *vis a tergo* derived from the force of the absorption itself.—With the reception of the nutritious fluid into the vessels, commences its real preparation for Organization. Up to that period, it cannot be said to be in any degree *vitalized;* the changes which it has undergone being only of a chemical and physical nature, and such as merely *prepare* it for subsequent assimilation. But in the passage of that which has been taken up by the Blood-vessels, through the Liver, very important changes are effected in its condition, whereby it is brought to a state more nearly corresponding with true Blood. And in like manner, the Chyle, in passing through the long and tortuous system of Absorbent vessels and glands, undergoes changes which, with little chemical difference, manifest themselves by a decided alteration in its properties; so that the chyle of the Thoracic duct is evidently a very different fluid from the chyle of the Lacteals, approaching much nearer to blood in its general characters. These characters are such as indicate that the process of organization and vitalization has commenced; as may be known alike from the microscopic appearance of the fluid, and from the actions it performs when removed from the body. The Chyle thus modified is conveyed into the Sanguiferous system of vessels, and flows directly to the heart; by which it is transmitted, with the mass of the blood, to the lungs. It there has the opportunity of excreting its superfluous carbonic acid, and of absorbing oxygen; and

probably acquires gradually the properties by which the blood previously formed is distinguished, thus becoming the *pabulum vitæ* for the whole system.—The fluid which is brought by the Lymphatic system, from those parts of the organism to which it is distributed, is obviously of a character no less nutritive than the chyle, though formerly regarded as excrementitious; its source appears to be partly in the serous transudation which escapes from the blood-vessels into the substance of the tissues, the superfluity of which is taken up again and carried back into the circulation by the lymphatics; and partly, it may be, in the re-solution of such portions of the tissues themselves, as, though dead, are not in a state of decomposition that prevents their components from being again made available as nutritive materials. The Lymph, like the chyle, seems to undergo an elaborating process in its passage towards the thoracic duct, whereby it is gradually assimilated to blood in its nature.

380. The *Circulation* of the Blood through the tissues and organs which it is destined to support, is a process evidently necessary, alike for supplying them with the nutritious materials which are provided for the repair of their waste, and for removing those elements of their fabric which are in a state of incipient decomposition. In the lowest classes of organized beings, every portion of the structure is in direct relation with its nutritive materials; it can absorb for itself that which is required; and it can readily part with that of which it is desirable to get rid. Hence, in such, no general circulation is necessary. In Man, on the other hand, the digestive cavity occupies so small a portion of the body, that the organs at a distance from it have no other means than their vascular communication affords, of participating in the results of its operations; and it is moreover necessary, that they should be continually furnished with the organizable materials, of which the occasional operation of the digestive process would otherwise afford only an intermitting supply. This is especially the case, as already mentioned, with the Nervous system, which is so predominant a feature in the constitution of Man; and we accordingly find both objects provided-for, in the formation of a large quantity of a semi-organized product, which contains within itself the materials of all the tissues, and is constantly being carried into relation with them.—The propulsion of the Blood through the large trunks, which subsequently divide into capillary vessels, is due to the contractions of a hollow muscular organ, the Heart; but these, like the peristaltic movements of the alimentary canal, are quite independent of the agency of the Nervous system; and are therefore to be referred to the class of Organic movements, such as occur in Vegetables. The rate and force of the Heart's movements are greatly influenced, however, by conditions of the Nervous system; and these also, by calling into play the contractility of the walls of the Arteries, exert a powerful influence upon their calibre, and consequently upon the distribution of blood to particular parts and organs, as we see in the acts of blushing and erection.

381. Upon the circulation of the blood through all parts of the fabric, depends in the first place the *Nutrition* of the tissues. Upon this subject, formerly involved in the greatest obscurity, much light has recently been thrown by Microscopic discovery; it being now understood (as explained in the preceding Chapter), that the continued growth and renewal of each tissue is effected by a continuation of a process essentially similar to that

by which it was first developed. The greatest difficulty, in the present condition of our knowledge, is to comprehend the reason why such a variety of products should spring up in the first instance; when the cells in which they all originate, appear to be so exactly alike. The important discoveries now referred-to, are not confined to healthy structures; for it has been ascertained, that diseased growths have a similar origin and mode of extension; and that the *malignant* character, assigned to Cancer, Fungus Hæmatodes, and other such productions, is partly connected with the fact, that they are composed of cells which undergo little metamorphosis, and retain their reproductive power; so that from a single cell, as from that of a Vegetable Fungus, a large structure may rapidly spring up, the removal of which is by no means attended with any certainty that it will not speedily re-appear, from some germs left in the system.—The independent vitality of the cells in which all organized tissues originate, might be of itself a satisfactory proof that, in Animals, as in Plants, the actions of Nutrition are effected by the powers with which they are individually endowed; and that, whatever influence the Nervous system may have upon them, its agency is not essential to their performance. Moreover, it is certain that no formation of nervous matter takes place in the embryonic structure, until the processes of Organic life have been for some time in active operation. The influence which the Nervous System is known to have upon the function of Nutrition, is probably exerted in two ways; first, through its power of regulating the diameter of the arteries and capillaries, by which it controls in some degree the afflux of blood; and secondly, through the more direct relation of the Nervous force to those other forms of Vital agency, which manifest themselves in the growth, development, and maintenance of the living tissues (§ 352).

382. The continual disintegration to which the living tissues are subject, from the various causes already referred-to, renders it necessary that a means should be provided for conveying away the waste, as well as for supplying the new material. This is partly effected by the Venous circulation; which takes up a large part of the products of incipient decomposition, and conveys them to organs of *Excretion*, by which they may be separated and cast forth from the body. The first product of the decay of all organized structures, is *carbonic acid;* and this is the one, which is most constantly and rapidly accumulating in the system, and the retention of which, therefore, within the body is the most injurious. Accordingly we find a most important organ—the Pulmonary apparatus—adapted to remove it; and to this the whole current of Venous blood passes, before it is again sent through the system. The efficient performance of this function of *Respiration* is so essential to the well-being of warm-blooded animals, that a special heart is provided for propelling the blood through their lungs, in addition to the one possessed by most of the lower animals, the function of which is the propulsion of the blood through the system. In these organs, the blood is subjected to the influence of the atmosphere, whereby the carbonic acid with which it was charged, is removed and replaced by oxygen; and this change takes place through the delicate membrane that lines the air-cells of the lungs, in accordance with the physical law of the mutual diffusion of gases. The introduction of oxygen into the blood is necessary for the maintenance of those peculiar vivifying powers, by which the Nervous and Muscular systems are kept

in a state fit for activity; and its union with their elements appears to be a necessary condition of the manifestation of their peculiar powers. Of this union, carbonic acid is one of the chief products; and we shall find that the demand for oxygen, and the excretion of carbonic acid, vary according to the amount of nervo-muscular action put forth. The continual formation of carbonic acid, in this and other interstitial changes, has a most important purpose in the vital economy, that of keeping up its temperature to a fixed standard; for the union of carbon and oxygen in this situation may be compared to a process of slow combustion, and, in combination with other combustive processes (in which hydrogen, sulphur, phosphorus, &c., undergo oxidation), it is the principal means of sustaining the independent heat of the 'warm-blooded' animal. There is in the system a certain self-adjusting power, whereby the consumption of the pabulum provided for the combustive process is regulated according to the external temperature; so that whilst, the external temperature being the same, the amount of carbonic acid excreted varies with the degree of muscular exertion made by the individual, any depression of the external temperature, requiring an augmented production of heat, occasions an increased combustion of the oxidizable solids of the body, which is indicated by an increase in the exhalation of carbonic acid from the lungs.—The interchange of oxygen and carbonic acid between the atmosphere and the blood, can only be kept up by a continual renewal of the air in the interior of the lungs, and of the blood in their capillaries. The former is effected by a set of muscular movements that depend on the 'reflex' power of certain nervous centres, and not on any exertion of the will of the individual. It is not even requisite that he should be conscious of their performance; the ordinary power of the stimulus that excites the movement, not being sufficient to cause itself to be felt, unless attention be specially directed to it. But if the respiratory movements be suspended for a short time, sensations of distress are soon experienced, which rapidly augment with the continuance of the suspension; and no exertion of the will can any longer prevent the performance of the movements which are appropriate to relieve them. Thus we see that these movements, although placed in Man under the control of the Will to such an extent as to enable him to regulate them in the actions of speech, are in themselves quite as independent of that will, as are those of the Heart, whose automatic power has been already alluded-to.

383. The function of the Liver as an excreting organ is, like that of the lungs, two-fold: it separates from the blood a large quantity of the superfluous *hydro-carbon*, which it acquires in circulating through the tissues; and it combines this with other elements (§§ 67–71), into a secretion, which is of great importance in the digestive process. The hepatic circulation, however, is not kept up by a distinct impelling organ; but the venous blood from the abdominal viscera (and, in the lower Vertebrata, that from the posterior part of the body) passes through the Liver on its return to the heart.—But further, all animal substances have a tendency, during their decomposition, to throw off nitrogen, as well as carbon; and this nitrogen, in combination with other elements, forms those peculiar *azotized* compounds (§§ 51–63), which it is the special function of the Kidney to eliminate from the circulating fluid. The most characteristic of these in Man, namely *urea*, contains a larger pro-

portion of nitrogen than is found in any other organic compound; and is identical in its chemical nature with cyanate of ammonia. Its production seems in great part to depend upon the disintegration of the muscular tissue; but there is also evidence that it may result from the retrograde metamorphosis of albuminous or even of gelatinous matters circulating in the blood. The action of the kidneys is equally essential to the continued performance of the other vital functions, with that of the lungs and liver; since death invariably follows its suspension, unless some other means be provided by Nature (as occasionally happens), for the separation of its characteristic excretion from the circulating blood.

384. The various Secretions which have not already been adverted-to, appear for the most part to have for their object the performance of some special function *in* the system, rather than the conveyance *out* of it of any substances which it would be injurious to retain. This is the case, for example, in regard to the secretion of the Lachrymal, Salivary, and Mammary Glands, as well as with that of the Mucous and Serous Membranes. The Excretion of fluid from the cutaneous surface, however, appears to answer two important purposes,—the removal from the body of a portion of its superfluous fluid, containing products of decomposition,—and the regulation of its temperature. Just as, by the action of the Lungs, the conditions are supplied, by which the temperature of the body is kept up to a certain standard, so, by that of the Skin, it is prevented from rising too high; for by the continual excretion from its surface, of fluid which has to be carried off by evaporation, a degree of cold is generated, which keeps the calorific processes in check; and this excretion is augmented, in proportion to the elevation of the external temperature, which seems, in fact, the direct stimulus to the process.—In all forms of *true* Secretion, the selection of the materials to be separated from the blood, is accomplished, like selective Absorption, by the agency of *cells.* These are developed in the interior of the secreting organ; and when they are distended with the fluid they have imbibed, their term of life appears to have expired, so that they burst or liquefy, yielding their contents to the ducts, by which the secreted product is conveyed away. In the case of Adipose tissue, we have an instance in which the secreted product (separated from the blood by the cells of which this tissue essentially consists) is not carried out of the body, but remains to form a constituent part of it.—The regulation of the amount of fluid in the vessels, is provided in a kind of *safety-valve* structure, existing in the Kidneys, which readily permits the escape of aqueous *fluid* from the capillary vessels, into the urinary canals, by a process of physical transudation, which is altogether distinct from the secretion of the *solid* matter, which it is the office of the Kidneys to separate from the circulating blood. Hence, if the excretion of fluid from the skin be checked by cold, so that an accumulation would take place in the vessels, the increased pressure within them causes an increased escape of water through the kidneys.

385. There is no sufficient reason to believe, that the Nervous System has any more direct influence on the process of Secretion, than it has been stated to have on that of Nutrition. That each glandular organ has an independent action of its own, in virtue of the endowments of its component cells, can scarcely now be doubted. Still, daily experience teaches that almost every secretion in the body is affected by states of mind,

which must operate through the nerves; and this may be fairly accounted for in part by the remarkable influence which the Nervous system possesses over the Circulation, but must also be in part attributed to the special agency of the Nervous force upon the chemical or vital process of Secretion itself. The flow of the secreted fluids through their efferent ducts, seems to be principally caused by the proper contractility of these, which (like that of the heart and alimentary canal) is directly stimulated by the contact of their contents; but there is also evidence that this contractility may be affected (as it is in those two instances) by the nervous system. Where, as happens in the case of the urinary excretion, there is a reservoir into which it is received as fast as it is formed, for the purpose of preventing the inconvenience which its constant passage from the body would otherwise occasion, the power of emptying this reservoir is usually placed in some degree under the dominion of the will, although chiefly governed by reflex action. It is obvious that such a provision is by no means essential to the function; and that it has for its object the adaptation, merely, of that function, to the conditions of Animal existence.

386. Thus we see that when we enter, as it were, into the *penetralia* of the Animal system, and study those processes in which the development and maintenance of the material fabric essentially consist, we find them performed under conditions essentially the same as those which obtain in Plants; and we observe that the operations of the Nervous System have none but an indirect influence or control over them. It is, therefore, quite philosophical to distinguish these Organic Functions, or phenomena of Vegetative Life, from those concerned in the Life of Relation, or Animal Life. The distinction is, indeed, of great practical importance, and lies at the foundation of all Physiological Science; yet it is seldom accurately made, and a very confused notion on the subject is generally prevalent.*

387. The process of *Reproduction*, like that of Nutrition, has been until recently involved in great obscurity; and although it cannot be said to be yet fully elucidated, it has been brought, by late investigations, far more within our comprehension, than was formerly deemed possible. The close connection between the Reproductive and Nutritive operations, both as regards their respective characters, and their dependence upon one another, has long been recognised; and it is now rendered still more evident. Nutrition has not been unaptly designated, "a perpetual reproduction;" and the expression is strictly correct. In the fully-formed organism, the supply of alimentary material to every part of the fabric enables it to produce a tissue resembling itself; thus we ordinarily find true bone produced only in continuity with bone, nerve with nerve, muscle with muscle, and so on. Hence it would appear that, when a portion of tissue has once taken-on a particular *kind* of action, it continues to reproduce itself on the same plan. But in the developmental process it is different. A single cell is generated by certain preliminary actions, from which cell, all

* It has been commonly said, for example, that the function of Respiration is the connecting link between the two: the fact being, however, that the *true* process of Respiration is no more a function of Animal life, than is any ordinary process of secretion; but that, in order to secure the constant interchange of air, which is necessary to its performance, the assistance of the nervous and muscular systems is called-in, though not in a manner which necessarily involves either *consciousness* or *will*.

those which subsequently compose the embryonic structures, take their origin; and it is not until a later period, that any distinction of parts can be traced, in the mass of vesicles which spring from it. This distinction becomes more and more obvious as development advances; the form and position of the principal organs being first marked-out by peculiar aggregations of cells; and the intimate structure of each being gradually brought to the type which is characteristic of it.—Hence we may state the essential character of the function of Reproduction to consist in the production of a cell of most peculiar endowments; which, when supplied with nutriment, and acted-on by warmth, does not simply multiply itself so as to produce a mere aggregation of similar cells, but gives origin to a succession of broods, which undergo such heterogeneous transformations, as ultimately to evolve an organism capable of maintaining an independent existence, in which the number of different parts is equal to that of the functions to be performed, each separate part having an office distinct from that of the rest, and being specially adapted to it alone.

388. But, it will be inquired, how and where in the Human body (and in the higher Animals in general) is this embryonic vesicle produced, and what are the relative offices of the two sexes in its formation? This is a question which must still be answered with some degree of doubt; and yet observed phenomena, if explained by the aid of analogy, seem to lead to a very direct conclusion. The embryonic vesicle itself, like other cells, must arise from a germ; and reasons will be hereafter given for the belief, that this germ is the product of the admixture of the contents of the 'sperm-cell' of the male with that of the 'germ-cell' of the female; and that this admixture is requisite for the regeneration of that 'germinal capacity,' which is gradually expended in the developmental process. The operations immediately concerned in this function, as in that of Nutrition, —namely, the preparation of the 'sperm-cells' and of the 'germ-cells,' the act of fecundation, and the development of the ovum,—are not dependent upon nervous agency, and are but little influenced by it; and the functions of Animal Life are called into play, only in the preliminary and concluding steps of the process. In many of the lower Animals, there is no sexual congress, even where the concurrent action of two sets of organs, belonging to two separate individuals, is necessary for the process; for the ova are liberated by one, and the spermatozoa by the other, and the accidental meeting of the two produces the required result. In many Animals higher in the scale, the impulse which brings the sexes together is of a purely instinctive kind. But in Man, it is of a very compound nature. The instinctive propensity, unless unduly strong, is controlled and guided by the will, and serves (like the feelings of hunger and thirst) as a stimulus to the reasoning processes, by which the means of gratifying it are obtained; and a moral sentiment or affection of a much higher kind is closely connected with it, which acts as an additional incitement. Those movements, however, which are most closely connected with the essential part of the process, are, like those of deglutition, respiration, &c., simply reflex and involuntary in their character; and thus we have another proof of the constancy of the principle, that, where the action of the apparatus of Animal Life is brought into near connection with the Organic functions, it is not such as requires the operation of the purely animal powers, —sensation and volition. Thus, then, as it has been lucidly remarked,

"the Nervous System lives and grows within an Animal, as a parasitic Plant does in a Vegetable; with its life and growth, certain sensations and mental acts, varying in the different classes of Animals, are connected by nature in a manner altogether inscrutable to man; but the objects of the existence of Animals require, that these mental acts should exert a powerful controlling influence over all the textures and organs of which they are composed."

### 3. *Functions of Animal Life.*

389. The existence of *consciousness*, by which the individual (*le moi*, in the language of French physiologists) becomes *sensible* of impressions made upon its bodily structure,—and the power of *spontaneously* exciting contractions in its tissues, by which evident motions are produced,—are to be regarded as the characteristic attributes of the beings composing the Animal kingdom; although their possession by many of the tribes which seem to have their most appropriate place in that kingdom, is, to say the least, extremely doubtful.* Of the movements exhibited by Animals, there are many which are no more to be regarded as indications of consciousness, than are those executed by certain plants; being simply the expressions or manifestations of a peculiar kind of vital force in the tissues by whose instrumentality they are performed. Such movements, in the lowest tribes, probably bear a much greater proportion to the whole amount of those exhibited by the beings, than they do in the higher; whilst those which we may regard as specially dependent on a nervous system, appear to constitute but a small part of their general vital actions. The life of such beings, therefore, bears a much closer resemblance to that of the Vegetable, than to that of the higher Animal. Their organic functions are performed with scarcely more of sensible movement, than is seen in plants; and of the motions which they do exhibit (nearly all of them *immediately* concerned in the maintenance of the organic functions), it is probable that many are the result of the simple contractility of their tissues, called into action by the stimuli directly applied to them. It is scarcely possible to imagine that such beings can enjoy any of those higher mental powers, which Man recognises by obervation on himself, and of which he discerns the manifestations in those tribes, which, from their nearer relation to himself, he regards as more elevated in the scale of existence.—If we direct our attention, on the other hand, to the *psychical* † operations of Man, as forming part of his general vital actions, we perceive that the proportion is completely reversed. So far from his Organic life exhibiting a predominance, it appears entirely subordinate to his Animal functions, and seems destined only to afford the conditions for their performance. If we could imagine his nervo-muscular apparatus to be isolated from the remainder of his corporeal structure, and to be endowed in itself with the power of maintaining its integrity, we should have all that is essential to our idea of Man. But, as at present constituted, this apparatus is dependent, for the conditions of its functional activity, upon the

* See "Princ. of Phys., Gen. and Comp.," CHAP. V.

† Here and elsewhere this term will be employed in its most extended sense, to designate *all* the mental operations,—whether intellectual, emotional, or instinctive,—of which Man's nervous system is the instrument.

nutritive apparatus; and the whole object of the latter appears to be the supply of those conditions. That his mental activity should be thus made dependent upon the due supply of his bodily wants, is a part of the general scheme of his probationary existence; and the first excitement of his intellectual powers is in a great degree dependent upon this arrangement.

390. The ministration of the Nervous System to purely Animal life, obviously consists in its rendering the mind cognizant of that which is taking place around, and in enabling it to act upon the material world, by the instruments with which the body is provided for the purpose. It is important to observe, that every method at present certainly known, by which Mind can communicate with Mind, involves in the first place, a generation of nervous force, which excites muscular contraction; secondly, a physical change determined by that contraction, the medium of which may be sound, light, or motion; and thirdly, the operation of this physical change as an 'impression' upon the sensory nerves, and through them upon the sensorial ganglia, of the other party. Such is the case, for example, not only in that communication which takes place by language, whether written or spoken; but in the look, the touch, the gesture, which are so frequently more expressive than any words can be; and thus we see that our interchange of ideas and emotions which are most purely *psychical* in their nature, can only be accomplished through the intermediation of *physical* forces. That imperfections in such communication are thus involved in the very nature of our present condition, and that all the higher operations of the mind are trammelled and restricted by the limited powers of its corporeal instrument, is a matter of constant and indubitable experience. On the other hand, that in a future state of being, the communion of mind with mind will be more intimate, and that Man will be admitted into more immediate converse with the Supreme Intelligence, appears to be alike the teaching of the most comprehensive Philosophical inquiries, and of the most direct Revelation of the Divinity.

391. The Organs of Sense are instruments, which are adapted to enable particular nerves to receive impressions from without; of a kind, and in a degree, of which they would not otherwise be sensible. Thus, although the simple mechanical impression produced by contact of a hard body, produces such a change in it, as, being propagated to the central sensorium, excites sensation there, it is evident that a nerve must be peculiarly modified at its peripheral expansion to receive its impressions from the undulations of the air; still more, to be susceptible of the impressions produced by those undulations to which most Natural Philosophers now attribute the transmission of light. And, even when this has been provided for, by some modification in the structure or arrangements of the nerve-fibres themselves, or of the vesicular matter in connection with them, a further provision is still required for giving to the mind a distinct consciousness of external objects in all their variety of shapes, colours, lights and shadows, &c.; or for enabling it to form ideas of the direction, pitch, quality, &c., of sonorous undulations. There is reason to believe that many among the lower Animals, which cannot *see* objects around them, are conscious of the influence of light; and thus the distinction between the mere reception of the impression, and

the excitement of a visual perception, becomes evident. The former may take place through the intervention of nerves, whose sensory extremities offer no extraordinary peculiarities: the latter can only be received through the medium of an instrument, which shall, from the mixture of rays falling equally upon every part of its surface, produce an optical image, and then impress it upon the expanded surface of the nerve; so that, each fibril receiving a distinct impression, the mind may form *its* picture by the combination of the whole. That this is, in fact, the share which the organs of Special Sense bear in the general endowments of the whole apparatus, may be inferred especially from the conformation of the Eye; which is in every respect a merely *optical* instrument, of the greatest beauty and perfection, adapted to form upon the retina, in the most advantageous manner, the images of surrounding objects in all their variations. There can be little doubt, that the structure of the Ear is arranged to do the same for the sonorous vibrations, which the eye does for the rays of light; that is, through its means, the undulations which strike upon the external surface of the organ are separated and distinguished, those of a like kind being brought together upon one division of the nerve, and those of another order upon a different set of fibres; so that the different kinds of sound, and the peculiar quality and direction of each, may be discriminated; whilst, by the concentration of all the impressions of the same character, a higher amount of force is given to them. The apparatus which ministers, however, to the sense of Smell, is far less complete in its endowments; for it serves only, in Man at least, for the discrimination of odorous emanations, and affords no guidance with regard either to their direction or their source. In fact, the kind of information which Man receives through this sense, seems very much akin to that which the lowest animals possessing visual organs can derive from *their* employment. Still a special organ of sense is required, to enable the olfactive nerve to be impressed by the peculiar agency of odorous emanations; which, whatever be its nature, has no operation upon ordinary sensory surfaces. It is not a little remarkable, that the speciality of organization of the nerves of Sight, Hearing, and Smell, renders them incapable of receiving ordinary mechanical impressions; so that the contact of solid substances with the sensory surfaces which they supply is not felt, except through the instrumentality of other nerves; and no irritation of their trunks, mechanical or otherwise, gives rise to feelings of pain. The sense of Taste, however, though special in regard to the peculiarity of the impressions which its organ is adapted to receive, is closely akin to that of Touch in the conditions under which it is exercised; the absolute contact of the sapid substance with the sensory surface being requisite; and the papillary organs in which the gustative nerves may be said to originate, being essentially the same in structure with those of ordinary tactile surfaces.

392. The Brain and Spinal Cord of Man, in which by far the greater part of the afferent nerves terminate, and from which nearly all the motor nerves arise, may be considered as made up of an aggregation of a number of distinct ganglionic centres, each of which has its own special endowments, and is connected with nervous trunks of its own.—Commencing with the *Spinal Cord*, we find, on comparing it with the gangliated column of Articulated animals, that it really consists of a series

of ganglia disposed in a longitudinal line, which have coalesced with each other; each ganglion being the centre of the 'nervous circle' proper to one vertebral segment of the trunk. Throughout the entire series, we find no other endowment than that of reacting upon an excitant; this excitant being either conveyed by the afferent nerve-trunks, or transmitted downwards from the higher parts of the nervous system. No impression which is limited to this series of ganglia, excites any sensorial change; so that we may consider the Spinal Cord as the special instrument of the 'excito-motor' division of the functions of the nervous system. The ordinary Spinal nerves are distributed to the sensory surfaces and to the muscular apparatus of the body generally; but at the summit of the Cord we find a peculiar set of ganglionic centres, included in that part which is distinguished as the *Medulla Oblongata*, whose nerves are distributed to the organs of Respiration, Deglutition, &c., and whose function consists in sustaining the muscular movements whose performance is essential to the continuance of these functions. The movements in question are purely *reflex;* and there is no other reason for distinguishing the endowments of the Medulla Oblongata from those of the Spinal Cord, save that which arises out of the speciality of the purposes to which the movements are subservient.—At the summit of the Spinal Cord, and partly lodged in the substance of the Medulla Oblongata, we find the series of *Sensory Ganglia,* which may in their totality be considered as making up the *Sensorium.* This includes the centres to which proceed the nerves of 'special sense;' and we may probably rank with it a pair of ganglionic masses (the 'thalami optici'), towards which certain afferent fibres of the spinal trunks appear traceable, that do not find their ganglionic centre in the spinal ganglia, but seem to pass upwards to the sensorium, that they may there excite sensational changes of the 'common' or tactile kind. From these Sensory Ganglia, we do not find any motor trunks ostensibly originating; but fibres pass downwards from them into the Spinal cord, which either directly enter its efferent nerve-trunks, or which serve to excite to action the ganglia from which those trunks arise; so that 'reflex' actions are performed by the instrumentality of the sensorial ganglia, which, however, differ from those of the spinal cord, in requiring Sensation as a necessary link in the series of changes. The Sensory ganglia are, therefore, the centres of the *consensual* or *sensori-motor* actions.—The whole of this series of ganglionic centres constitutes the purely *automatic* portion of the Nervous system, whose operations, when not interfered-with by the Cerebrum, are, like those of Insects (whose entire nervous system corresponds with the automatic portion of that of Man), entirely *instinctive.* And their independent action seems to be the source, not merely of all those movements which are originally instinctive, but of many others which come by *habit* to be performed involuntarily when the attention is otherwise engaged; these have been termed 'secondarily automatic.'

393. But in Man, as in all other animals possessed of Intelligence, by which the Will is animated and directed, we find a superadded organ, the *Cerebrum,* which is not itself the centre of either sensory or motor nerves, but which derives from the automatic apparatus just described all its stimulus to action, and employs it as its instrument of operation on the muscular system. The functions of this organ, which are purely

mental, are first excited by the sensations called forth in the Sensory ganglia, which, being conveyed to the cerebrum, give rise through its instrumentality to Ideas; and these may become the subject of Reasoning processes, which react on the body by an exertion of the Will. Although it has been customary to regard the Will as directly operating on the muscular system, yet we shall hereafter find reason to consider it as exerting its power through the medium of the Automatic apparatus, to which its determinations are transmitted, and by which they are carried into execution. But ideas with which the feelings of pleasure or pain are associated, constitute Emotions; and these, if strongly excited, may act downwards upon the muscles through the medium of the automatic apparatus, quite independently of the will, and even in opposition to it. And there are certain peculiar states of the mind, in which the power of the Will is completely suspended, and in which Ideas alone seem capable of exciting movements. Thus the Cerebral ganglia are the instruments of two kinds of action that may be considered essentially 'reflex,' as being executed in respondence to external impressions, without any volitional or purposive direction; these impressions either acting simply through ideas, and thus producing *ideo-motor* actions, or through ideas with which feelings are associated, and thus producing *emotional* movements.

394. Another division of the Nervous System appears to have for its object to combine and harmonize certain muscular movements immediately connected with the maintenance of Organic life; and to bring these into relation with certain conditions of the mind. There is further reason to believe that it also influences, and brings into connection with each other, the processes of Nutrition, Secretion, &c.; though these, like the muscular movements just mentioned, are essentially independent of it.—This portion of the nervous apparatus is commonly known under the name of the *Sympathetic* system; it has a set of ganglionic centres and nerves of its own; but it is also intimately blended with the Cerebro-spinal system, receiving fibres from it, and also sending fibres into it.

395. With reference to that class of operations of which the Cerebrum is the instrument, it is well here to explain that, though the Physiologist speaks of the intellectual powers, moral feelings, &c., as *functions* of the Nervous System, they are not so in the sense in which the term is employed in regard to other operations of the bodily frame. In general, by the *function* of an organ, we understand some change which may be made evident to the senses, as well in our own system, as in the body of another. Sensation, Thought, Emotion, and Volition, however, are changes imperceptible to our senses by any means of observation we at present possess. We are cognizant of them in ourselves, without the intervention of those processes by which we observe material changes external to our minds; but we judge of them in others, only by inferences founded on the actions to which they give rise, when compared with our own. When we speak of sensation, thought, emotion, or volition, therefore, as functions of the Nervous System, we mean only that this system furnishes the conditions under which they exist in the living body; and we leave the question entirely open, whether the Ψυχη has or has not an existence independent of that of the material organism, by which it operates in Man, as he is at present constituted.

# CHAPTER VII.

## OF FOOD, AND THE DIGESTIVE PROCESS.

### 1. *Of Food, its Nature and Destination.*

396. The substances which are required by Animals for the development and maintenance of their fabric, are of two kinds;—the Organic and the Inorganic. The Organic alone are commonly reckoned as aliments; but the latter are really not less requisite for the sustenance of the body, which speedily disintegrates, if the attempt be made to support it upon any organic compounds in a state of purity. In all ordinary articles of diet, however, the Inorganic matters are present in the requisite proportion; and hence they have very commonly escaped notice. The nature of these substances, and the mode in which they are introduced into the body, have been already treated-of (CHAP. II. SECT. 6).

397. The Organic compounds usually employed as food by Man, are partly derived from the Animal, and partly from the Vegetable kingdom; and they may be conveniently arranged under the four following heads:*—1. The *Saccharine* group, including all those substances, derived from the Vegetable kingdom, which are analogous in their composition to Sugar; consisting of oxygen, hydrogen, and carbon alone; and having the first two present in the proportions to form water. To this group belong starch, gum, woody fibre, and the cellulose of Plants, which closely resemble each other in the proportion of their elements, and which may be converted into Sugar by chemical processes of a simple kind; whilst Alcohol, which is derived from Sugar by the process of fermentation, has a composition which rather connects it with the next group.—2. The *Oleaginous* group, including oily matters, whether derived from the Vegetable kingdom, or from the fatty portions of Animal bodies. The characteristic of this class lies in the great predominance of hydrogen and carbon, the small proportion of oxygen, and the entire absence of nitrogen.—3. The *Albuminous* group, comprising all those substances, whether derived from the Animal or the Vegetable kingdom, which are closely allied to Albumen, and through it to the Animal tissues generally (§ 20), in their chemical composition. In this group, a large proportion of azote is united with the oxygen, hydrogen, and carbon of the preceding.—4. The *Gelatinous* group, consisting of substances derived from Animal bodies only, which are closely allied to Gelatin in their composition. These also contain azote; but the proportion of their components differs from that of the preceding.—There are many other substances, however, which, though truly alimentary, and consumed to a considerable amount, cannot be legitimately placed under either of the above heads; such are, for example, the Vegetable Acids.

* Dr. Prout's classification of alimentary substances is here adopted, with a slight modification; not as being altogether unexceptionable, but as being, in the Author's opinion, the most convenient hitherto proposed.

398. The compounds of the *Saccharine* group cannot, without undergoing metamorphosis, form part of any Animal tissue; as there is none which they at all resemble in composition. It has been shown, however, that they are convertible, within the animal body, into those of the *Oleaginous* group (§ 40), and may thus, like the latter, be applied to the formation of the Adipose and Nervous tissues.—But the amount of these substances which is thus employed, is a very small part of that which is ordinarily introduced as food; and by far the larger proportion of them is made subservient to the maintenance of the Heat of the body by the combustive process. The Sugar which is taken-in as such, being dissolved and absorbed into the current of the circulation, appears to undergo a speedy metamorphosis into *lactic acid*, which is the form under which it is finally oxidized and burned-off (§ 49); and Starch is made capable of undergoing the same change, by being first converted into Sugar during the digestive process. Oleaginous matters do not seem to undergo any change preliminary to their oxidation, save their reduction to a state of very fine division.—We shall presently see (§ 401) that a very considerable difference exists between the Saccharine and Oleaginous matters, in regard to their relative calorifying powers.—That none of these *non-azotized* substances can be made capable, by metamorphosis or combination within the Animal body, of taking the place of the *azotized* substances as 'histogenetic' or 'plastic' compounds, may now be regarded as one of the most certain facts in Physiology; the concurrent evidence of experiment and observation leading to the conclusion, that in Plants alone can any production of azotized compounds take place, and that Animals are in consequence directly or indirectly dependent upon the Vegetable kingdom for their means of subsistence. If animals be fed exclusively upon Saccharine or Oleaginous substances, of any kind or in any combination whatever, they speedily perish with symptoms of Inanition; and the only assistance which such food affords in the prolongation of life, is derived from its calorific power (§ 375).

399. The application of the substances forming the *Albuminous* group, to the support of the Animal body, by affording the materials for the nutrition and re-formation of its tissues, and also for the maintenance of its heat, has been already sufficiently considered (CHAP. II). The proportions of carbon, hydrogen, oxygen, and nitrogen, of which all these substances are composed, appear to be identical; and they are all capable of being reduced by the digestive process to the condition of albumen. Hence it is a matter of little consequence, except as regards the proportions of inorganic matters with which they may be respectively united, whether we draw our histogenetic materials from the flesh of animals, from the white of egg (albumen), from the curd of milk (casein), from the grain of wheat (gluten), or from the seed of the pea (legumin). Neither of these substances, however, can long sustain life when it is used by itself; for it has been experimentally ascertained that by being made to feed constantly on the same substance,—boiled white of egg, for instance, or meat deprived of the principle (osmazome) that gives it flavour,—an animal may be effectually starved; its disgust at such food being such, that even if this be swallowed, it is not digested.* The

* It is very interesting to remark (with Dr. Prout) that, in the only instance in which Nature has provided a *single* article of food for the support of the animal body, she has

organized fabric of Animals contains, as we have seen, a large quantity of *Gelatin*. It seems certain that this substance may be produced out of fibrin and albumen; since in animals that are supported on these alone, the nutrition of the gelatinous tissues does not seem to be impaired. But it has been commonly supposed that gelatin taken-in as food may serve for the growth and maintenance of these tissues; even though it may be incapable of conversion to the albuminous type. It is very doubtful, however, whether Gelatin can render even this service. For all our knowledge of the history of the development of the Gelatinous tissues would lead us to regard them as secondary products, which take their origin in a fibrinous blastema, and can only be generated by the metamorphosis of protein-compounds (§§ 28, 29, 222, 223). If these views be correct, it follows that the alimentary value of gelatin must be limited to its calorific power; its hydrocarbon being separated from its highly-azotized portion, and the former being oxidized and eliminated through the lungs, whilst the latter will pass-off by the kidneys. And this view is confirmed by the observations of Frerichs on the result of the ingestion of large quantities of pure gelatin; this being a marked increase in the proportion of urea in the urine, with an elevation of its specific gravity from 1018 to 1030 or even 1034. Neither Leucine nor Glycine could be detected in the fluid; so that Gelatin seems to be subjected to the same metamorphosis that the protein-compounds undergo when they are taken in excess.*—That Gelatin cannot take the place of the albuminous compounds, has been fully demonstrated by the inquiries of the Commissions which have been appointed to investigate the subject in Paris and Amsterdam.† In so far, therefore, as the only azotized principles contained in soups, broths, &c., are of the gelatinous character, we must account these preparations as destitute of the power of nourishing the body; and the peculiar nutritive value which experience shows that such preparations possess in certain states of the system, must be attributed to the albuminous matters which they hold in solution, and to the readiness with which their gelatinous constituents are absorbed and applied (by the decomposition just explained) to the purpose of calorification.‡

400. The substances which cannot be arranged under either of the preceding groups, are, for the most part, of the non-azotized class; and, as they mostly consist of compounds in which the hydrogen and carbon are not combined with their full equivalents of oxygen, they are made

mingled articles from the first three of the preceding groups. This is the case in *Milk*, which contains a considerable quantity of an albuminous substance, *casein*, which forms its curd; a good deal of *oily* matter, the butter; and no inconsiderable amount of *sugar*, which is dissolved in the whey. The proportions of these vary in different Mammalia; and they depend in part upon the nature of the food supplied to the Animal that forms the milk; but the substances are thus combined in every instance.

* See Frerichs' article *Verdauung* in "Wagner's Handwörterbuch."—The Author is indebted to Dr. Gull for directing his attention to this view of the incapacity of Gelatin for *any* histogenetic purpose.

† See the Report of the French 'Gelatin Commission,' in the "Compt. Rend." Août, 1841; and that of the Amsterdam Commission in "Het Instituut," No. 2, 1843, and "Gazette Médicale," Mars 16, 1844.

‡ The common notion of the great nutritive value of soups, &c., whose supposed 'strength' is indicated by the firmness with which they gelatinize on cooling, is one of those popular dietetic prejudices, of which it is peculiarly incumbent on the Medical Profession to disabuse their patients.

to contribute to the calorifying process by undergoing oxidation within the system, so as to be excreted in the form of carbonic acid and water.

401. By rules based on the foregoing data, then, we may estimate the relative value of different articles of food for the two distinct purposes of tissue-formation and the production of heat. For the proportion of albuminous matter which any substance may contain, furnishes the measure of its histogenetic value; whilst the proportion of hydro-carbon uncombined with oxygen affords the means of estimating its calorific power when oxidized. As in almost every alimentary substance, whether vegetable or animal, the two classes of compounds are mingled, the percentage of Nitrogen which it may contain affords a tolerably correct measure of the amount of albuminous matter which it includes, and therefore of its histogenetic value: where, on the other hand, the percentage of Nitrogen is the smallest, that of Hydro-carbon is the largest, and the proportion of the combustive material is the highest. The following Table* specifies this proportion in the case of various articles used as food; Human Milk being taken as the standard of comparison, and the quantity of Nitrogen it contains being expressed by 100. It must be borne in mind, however, that this substance is intended for the nourishment of a being, that passes nearly the whole of its time in a quiescent state; and must not be supposed to be adapted for the sole maintenance of the Human body in a state of activity. In fact, it is inferior in its proportion of Casein (the substance of which alone the azote forms a part) to the milk of most, if not all, other Mammalia; *their* young bringing their animal functions into exercise at a much earlier period than does the Human infant.

*Vegetable.*

| | | | | | |
|---|---|---|---|---|---|
| Rice | 81 | Oats | 138 | Peas | 239 |
| Potatoes | 84 | White bread | 142 | Agaricus russula | 264 |
| Turnips | 106 | Wheat | 119–144 | Lentils | 276 |
| Rye | 106 | Carrots | 150 | Haricot beans | 283 |
| Maize | 100–125 | Brown bread | 166 | Agaricus deliciosus | 289 |
| Barley | 125 | Agaricus cantharellus | 201 | Beans | 320 |

*Animal.*

| | | | | | |
|---|---|---|---|---|---|
| Human milk | 100 | Salmon, raw | 776 | Flounder, raw | 898 |
| Cow's milk | 237 | ——— boiled | 610 | ——— boiled | 954 |
| Oyster | 305 | Liver of Pigeon | 742 | Pigeon, raw | 756 |
| Yolk of eggs | 305 | Portable soup | 764 | ——— boiled | 827 |
| Cheese | 331–447 | White of egg | 845 | Lamb, raw | 833 |
| Eel, raw | 434 | Crab, boiled | 859 | Mutton, raw | 773 |
| —— boiled | 428 | Skate, raw | 859 | ——— boiled | 852 |
| Liver of crab | 471 | ——— boiled | 956 | Veal, raw | 873 |
| Mussel, raw | 528 | Herring, raw | 910 | —— boiled | 911 |
| ——— boiled | 660 | ——— boiled | 808 | Beef, raw | 880 |
| Ox liver, raw | 570 | ——— milt of | 924 | —— boiled | 942 |
| Pork-ham, raw | 539 | Haddock, raw | 920 | Ox lung | 931 |
| ——— boiled | 807 | ——— boiled | 816 | | |

It is not to be supposed, however, that any table of this kind, founded simply upon the Chemical composition of the various substances, can indicate their respective fitness as articles of diet; since this depends also

* Schlossberger and Kemp, in "Philosophical Magazine," Nov. 1845.

upon the facility with which they are reduced by the digestive process, and afterwards assimilated. Thus an aliment, abounding in nutritive matter, may be inferior to one which really contains a much smaller proportion, if only a part in the first case, and the whole in the second, be readily taken up by the system.—The calorific powers of the substances above enumerated, however, are not precisely in the inverse ratio to their histogenetic value; for, as the amount of heat given off in their combustion depends, not simply upon the amount of carbon and hydrogen they may contain, but upon the amount of their hydro-carbon over and above that which is already combined with oxygen, substances that are alike deficient in nitrogen may differ considerably in this respect. Thus in ordinary fat, the proportion of oxygen is only about 10 per cent, whilst that of hydro-carbon is at least 90 per cent; in alcohol, the proportion of oxygen is nearly 35 per cent to 65 per cent of hydro-carbon; in starch, the oxygen is $49\frac{1}{3}$ per cent, the hydro-carbon $50\frac{2}{3}$ per cent; in cane-sugar, the oxygen is $51\frac{1}{2}$, the hydro-carbon $48\frac{1}{2}$; and in grape-sugar, the oxygen is $53\frac{1}{3}$, the hydro-carbon $46\frac{2}{3}$. According to the estimate of Prof. Liebig,* the following are the relative calorific powers of these substances, the numbers expressing approximately the weights of each which must be taken-in as food, in order, with the same consumption of oxygen to keep the body at its proper temperature during equal times: fat, 100; starch, 240; cane-sugar, 249; grape-sugar, 263; spirits (containing 50 per cent of absolute alcohol), 266. The equivalent of lean flesh required to produce the same calorific effect with the foregoing, would be no less than 770.

402. It is obvious that the most *economical* diet will be that in which there is the most perfect apportionment of each class of constituents to the wants of the system; and these, on the principles formerly explained (§§ 374-6), will vary with the amount of muscular exertion put forth, and the lowering of the external temperature. Thus, for a man of ordinary habits, and living under a medium temperature, a diet composed of animal flesh alone is the least economical that can be conceived; for, since the greatest demand for food in his system is created by the necessity for a supply of carbon and hydrogen to support his respiration, this want may be most advantageously fulfilled by the employment of a certain quantity of non-azotized food, in which these ingredients predominate. Thus it has been calculated, that, since fifteen pounds of flesh contain no more carbon than four pounds of starch, a savage with one carcass and an equal weight of starch, could support life for the same length of time, during which another restricted to animal food would require five such carcasses, in order to procure the carbon necessary for respiration. Hence we see the immense advantage as to economy of food, which a fixed agricultural population possesses over those wandering tribes of hunters, which still people a large part both of the old and new continents. The mixture of the azotized and non-azotized compounds (gluten and starch), that exists in wheat-flour, seems to be just that which is most generally useful to Man; and hence we see the explanation of the fact, that, from very early ages, bread has been regarded as the "staff of life."—There are particular conditions of existence, however,

* "Familiar Letters on Chemistry," 3rd edit., p. 330.

under which life may be advantageously supported upon *animal* food alone. Thus the Guachos of South America, who pass the whole day in the saddle, and lead a life of constant activity resembling that of a carnivorous animal, scarcely ever taste anything but beef; and of this their consumption is by no means great; for the temperature of the surrounding atmosphere is so high, that the body has no occasion to generate more heat than is supplied by the combustion of the hydro-carbonaceous portion of the 'waste' of the tissues. Here, then, the demand for histogenetic material being at its maximum, and that for combustive materials at its minimum, the former supplies all that is requisite for the latter. Again, the Esquimaux and other dwellers upon the Arctic seas find in the bodies of the whales, seals, &c., whereon they subsist, that special supply of the very best combustive material, which alone can enable them to maintain their existence in a climate where the thermometer is for many weeks or months in the year at—40° or even lower, and where the amount of heat which must be generated within the body is four or five times that for which a diet of bread will suffice.—On the other hand, the general experience of the inhabitants of warm climates seems in favour of a diet chiefly or entirely *vegetable;* and its peculiar suitableness appears to consist in its affording an adequate supply of the plastic alimentary substances, in combination with farinaceous matters that give the requisite *bulk* to the food (§ 448), without affording more combustive material than the system requires,—the quantity of starch which undergoes conversion and is introduced as sugar into the circulation, being apparently governed rather by the demands of the respiratory process, than by the amount ingested, and the remainder being voided again unchanged.

403. The *mixed* diet, to which the inclination of Man in temperate climates seems usually to lead him (when circumstances allow that inclination to develope itself freely), appears to be fully conformable to the construction of his dental and digestive apparatus, as well as to his instinctive propensities. And whilst on the one hand it may be freely conceded to the advocates of 'Vegetarianism,' that a well-selected vegetable diet is capable of producing (in the greater number of individuals) the highest *physical* development of which they are capable, it may on the other hand be affirmed with equal certainty, that the substitution of a moderate proportion of animal flesh is in no way injurious, whilst, so far as our evidence at present extends, this seems rather to favour the highest *mental* development. If, indeed, we take a comprehensive survey of the conditions of the various races of Man at present inhabiting the earth, we cannot help being struck with his adaptiveness to a great variety of circumstances, as regards climate, mode of life, diet, &c. And we can scarcely avoid the conclusion, that the Creator, by conferring upon him such an adaptiveness, intended to qualify him for subsisting on those articles of diet, whether animal or vegetable, which are most readily attainable in different parts of the globe; and thus to remove the obstacle which a necessary restriction to any one kind of food would have otherwise opposed to his universal diffusion. If we were to bring together the habitual diet-scales of the several races of men which people the surface of our globe, we apprehend, that the diversities which they would present, would be scarcely less strange than those which exist

among the regimens of the most dissimilar species of Mammalia. We should find the purely animal-feeding on the one hand, the pure vegetarians on the other. Among the former we should find some who devour animal flesh, others fish, and others fowl, while others are even insectivorous; then, again, we should encounter some who devour their food raw, others who cook it; some preferring it immediately that it has ceased to live, while others do not relish it until it has become almost putrescent. So among the vegetable-feeders, we should find some subsisting upon soft fruits, others upon hard grains, others again chiefly upon succulent herbage, and others upon roots so tough as to require artificial means for their reduction. In the various devices by which man has succeeded in availing himself of these, and in the various tastes which have led some to avail themselves of articles of food which others would loathe, we see the evidence of the same wise Design, as that which has given to different tribes of animals their respective preferences; and we deduce from the whole the conclusion, that Man is left by his Creator at perfect liberty to select that kind of nutriment which he finds most suitable to his tastes and to his wants; the former, when not absolutely vicious, being (there is strong reason to believe) an exponent of the latter, just as the simple desire for food is the exponent of the need for it in the system.

404. When the results of experience, then, are combined with the teachings of science, they seem to justify the following conclusions.

I. That a due adjustment of the Albuminous, Oleaginous, and Saccharine constituents of the food, to the varying conditions under which Man exists, is of the first importance; and that the question of the derivation of the first two of these constituents from the Animal or from the Vegetable kingdom is one of secondary character; each being capable of yielding them in adequate amount, and the only condition requisite being, that the articles of food shall be so selected as to supply the needful quantity. Thus a diet whose staple consists of potatoes or rice, contains by far too small an amount of albuminous matter in proportion to the farinaceous; but if to this be added a moderate quantity of meat, the proportion is assimilated to that which exists in wheaten bread, which may be taken as the standard for Man's alimentation in all but extremely cold climates. The failure of wheaten bread to supply what the system there requires, depends on nothing else than its deficiency in the oleaginous constituent; for although such a craving for fat meat is experienced by travellers in those climates, as has led to the belief that it is necessary for their support, yet recent experience has shown that a vegetable oil answers the same purpose, bread made from *maize* flour (which contains a large proportion of oleaginous matter) having been found to be just as efficacious as fat meat, both in supporting the muscular strength, and in maintaining the heat of the body.* On the other hand, maize-bread is found by experience to be far less adapted than wheaten bread for consumption in warm climates, being too 'heating' in its character; thus confirming the view already stated, as to the superiority of farinaceous matter as the principal combustive material, where the external temperature is high.—The same kind of difference should

* The Author makes this statement on the authority of Sir J. Richardson, who informs him that 2½ lbs. of maize-flour are considered to be the equivalent of 8 lbs. of meat.

be made in the winter and summer diet of the inhabitants of the temperate zone. For when the external temperature is low, an ample supply of oleaginous matter is indicated, and may be advantageously taken in the form of butter, cocoa, fat meat, or maize-bread. On the other hand, during the heat of summer, the more nearly the diet is assimilated to that of the natives of tropical climates, in the substitution of fruits and farinacea for oleaginous articles, the less will be the liability to disordered health in the autumn.*

II. Experience teaches, however, that it is not a matter of entire indifference, whether the Albuminous constituent be drawn from the Animal or from the Vegetable kingdom; for the use of a highly-animalized diet has a tendency to *raise*, and that of a vegetable diet to *lower*, the proportion of red corpuscles in the Blood (§ 161); whilst, by a due adjustment of the proportion of the two classes of components, the evil effects of the exclusive use of either may be prevented.

III. So, again, experience teaches what could scarcely have been anticipated theoretically;—namely, that, notwithstanding the power which the living body possesses of converting saccharine compounds into oleaginous, the ingestion of a certain amount of Oleaginous matter *as such* is necessary, or at least is favourable, to the maintenance of health. We see this provided in large quantity, in the first aliment prepared by nature for the offspring of the Mammalia; and it exists largely in the yolk of the egg of all Oviparous animals. In the ordinary diet of every nation on the globe,—whether this be animal, vegetable, or mixed,—we find one or more articles of an oleaginous nature; and there is a natural craving for such substances when they are completely withheld, which indicates that they serve some important purpose in the economy. Although this craving is so far affected by climate, that it leads to the largest consumption of oily matter where the extreme of cold has to be endured, it exists with no less intensity even in tropical regions; and we find the Hindoo adding his modicum of 'ghee' (or rancid butter) to the rice which constitutes his staple article of diet, with the same relish that the Esquimaux feels for his massive lumps of blubber.—It does not seem difficult to understand the *rationale* of this fact. It has been already pointed-out, that whilst the Adipose and Nervous tissues are the only portions of the Animal fabric into which fatty matter enters in any considerable proportion, yet that its presence has an important influence on the assimilation of albuminous matters, and seems essential to every act of cytogenesis (§ 42). We shall hereafter see (CHAP. VIII., SECT. 3), that it is probably in the Lacteal system that the two substances are brought into that mutual relation with each other which these purposes require; and thus

* There can be no doubt that a large proportion of the diseases of the digestive apparatus, which are so fatal among European residents in India and other tropical climates, result from the habitual ingestion of a much larger quantity of food, and this especially of a rich and stimulating character, than the system requires. The loss of appetite consequent upon the diminution of the demand for combustive material, is set down to the deleterious influence of the climate; and an attempt is made to neutralize this by artificial provocatives.—So, it seems probable that many of the "bilious attacks," which, in this country, are so frequent in early autumn, and which are commonly set down to the account of fruit (although the subjects of them have often abstained entirely from that article), are really the result of the presence of an excess of hydrocarbonaceous matter in the system, consequent upon over-feeding during the summer, and must be looked-on as the natural means by which it is got rid of.

it is obvious that, unless a conversion of saccharine into oleaginous matter can take place in the alimentary canal (of which there is no adequate evidence), no true chyle can be formed, except when oleaginous matters have formed part of the food. There is strong and increasing reason to believe, that a deficiency of oleaginous matter, in a state fit for appropriation by the nutritive processes, is a fertile source of diseased action, especially of that of a tuberculous character; and that the habitual use of it in larger proportion would operate favourably in the prevention of such maladies, as the employment of cod-liver-oil unquestionably does in their cure. A most remarkable example of this is presented by the population of Iceland; which, notwithstanding the concurrence of every one of the circumstances usually considered favourable to the scrofulous diathesis, enjoys a most remarkable immunity from it,—without any other assignable cause than the peculiarly oleaginous character of the diet usually employed.*

IV. Another of the results of experience, of which Science has not yet given a definite *rationale*, is the necessity of employing *fresh vegetables* as an article of Diet; the almost invariable consequence of the entire omission of them, being the development of that peculiar constitutional disorder which is known as *Scurvy.* That the deficiency of something which fresh vegetables can alone supply, is the essential cause of this disease (its operation being promoted, however, by other conditions, such as absolute deficiency of food, confinement, bad ventilation, depression of spirits, &c.), may now be regarded as a well-established fact;† and it is one which ought to have an important influence on our dietetic arrangements. For if the total withdrawal of these articles be productive of such a fearful depravation of the blood, as perverts every function to which the blood is subservient, a diminution of them below the standard requisite for the maintenance of health must necessarily involve a depravation similar in kind though less aggravated in degree; and this, if slight, may be expected to manifest itself, not so much in the production of idiopathic disorders, as in favouring any peculiar tendency to disease which may exist in the system, and in preventing or retarding recovery from its effects.‡ The employment of fresh fruits and of green vegetables seems especially indicated, where a general chronic disorder of nutrition indicates a perverted condition of the circulating material; and especially where there is a disposition to chronic inflammation, induration, and ulceration, in different parts of the body.

V. Finally, then, a well-arranged dietetic scheme ought to consist of such a combination of the Albuminous, Oleaginous, and Farinaceous constituents, as is most appropriate to the requirements of the system;—a larger measure of the *albuminous* being supplied, when an unusual amount

* See Dr. Schleisner's "Island undersögt fra lægevidenskabeligt Synspunct," or Report on the Sanitary Condition of Iceland; and the analysis of it in the "Brit. and For. Med.-Chir. Rev.," vol. v. p. 456.

† For a full inquiry into this subject, see the "Brit. and For. Med.-Chir. Rev.," vol. ii. 439.

‡ This "scorbutic tendency" was fully recognized by the past generation of physicians, who practised in those good old times when potatoes were a luxury, and green vegetables in the winter almost unknown, when the middle classes fed upon salted meat during a great part of the year, and when sagacious old women prescribed nettle-tea and scurvy-grass, with a course of lenitive "spring-physic," for the "cleansing of the blood."

of nervo-muscular exertion is put forth, and this supply being then most advantageously derived from animal flesh;—a larger measure of the *oleaginous* being required for the sustentation of the heat in a frigid atmosphere, and this being supplied equally well by the vegetable kingdom as by the animal;—and a larger proportion of the *farinaceous*, as a substitute for the oleaginous, being most favourable to health under a high atmospheric temperature. An habitual excess in the use of either of these constituents, above what the demands of the system require, tends towards the production of a particular 'diathesis' or constitutional state, which may manifest itself in a great variety of modes. Thus, an excess of the *albuminous* components, such as is only likely to occur when too large a proportion of animal food is employed, undoubtedly favours the *arthritic* diathesis, which seems to consist in the presence of imperfectly assimilated histogenetic substances and wrongly-metamorphosed products of disintegration, that are not duly eliminated in the kidneys; and this diathesis not only displays itself in gout and gravel, but modifies the course of other diseases. So, again, an excess of the *oleaginous* constituents of the food tends to the production of the *bilious* diathesis, in which, through the insufficient elimination of hydrocarbonaceous matters, the blood becomes charged with the elements of bile. The excess of *farinaceous* matters, moreover, especially when combined with a deficiency of the albuminous (as it too frequently is among those who are obliged by necessity to live chiefly upon a 'poor' vegetable diet), tends to the production of the *rheumatic* diathesis; which seems to consist, like the arthritic, in the mal-assimilation and wrong metamorphosis of the components of the tissues, but to be especially favoured by the presence either of lactic acid, or of some other product of the metamorphosis of the saccharine compounds. And, as already pointed out, the *deficiency* of oleaginous matters seems to tend to the development of the *scrofulous* diathesis; and that of fruits and fresh vegetables to the production of the *scorbutic*.*

405. The *absolute quantity* of Food required for the maintenance of the Human body in health, varies so much with the age, sex, constitution, and habits of the individual, and with the circumstances in which he may

* It is worthy of remark that in the times when even the wealthy lived during four or five months of the year almost exclusively upon meat, bread, and flour-puddings, and when, therefore, the diet was far too highly azotized, as well as deficient in fresh vegetables, arthritic, calculous, and scorbutic disorders were much more common than at present. The introduction and universal employment of the potato has unquestionably done much to correct these two tendencies; on the one hand, by diluting the azotized constituents of the food, so that, with the same bulk, a much smaller proportion of these is now introduced; and on the other, by supplying to the blood some element which is essential to the maintenance of its healthy condition. But with the diminution of the arthritic diathesis, which the experience of our older practitioners, and the medical writings of the last century, indicate as having taken place during that period, there has been an increase in the rheumatic;—a change which seems to have a close relation to this alteration in diet. And it seems not improbable, too, that this alteration in diet has much to do with that diminished power of sustaining active depletory treatment, which, according to the observations of practitioners of long experience, characterizes the present generation as compared with the preceding. But whilst there is a diminished capability of bearing large blood-lettings, violent purgation, &c., there is at the same time such an increased tendency to a favourable termination in many of those diseases for which they were formerly accounted necessary, as should remove all regret at this change of constitution. —On the question of 'Vegetarianism,' the Author may refer to his articles on that subject in the "Brit. and For. Med.-Chir. Rev.," vol. vi. pp. 76 and 399.

be placed, that it would be absurd to attempt to fix any standard which should apply to every particular case. The appetite is the only sure guide for the supply of the wants of each; but its indications must not be misinterpreted. To eat when we are hungry, is an evidently natural disposition; but to eat as long as we are hungry, may not always be prudent. Since the feeling of hunger does not depend so much upon the state of fulness or emptiness of the stomach, as upon the condition of the general system, it appears evident that the ingestion of food cannot *at once* produce the effect of dissipating it, though it will do so after a short time; so that, if we eat with undue rapidity, we may continue swallowing food long after we have taken as much as will really be required for the wants of the system; and every superfluous particle is not merely useless, but injurious. Hence, besides its other important ends, the process of thorough mastication is important, as prolonging the meal, and giving time to the system to be made acquainted (as it were) that the supply of its wants is in progress; so that its demand may be abated in due time to prevent the ingestion of more than is required. It is very justly remarked by Dr. Beaumont, that the cessation of this demand, rather than the positive sense of satiety, is the proper guide. "There appears to be a sense of perfect intelligence conveyed to the encephalic centre, which, in health, invariably dictates what quantity of aliment (responding to the sense of hunger and its due satisfaction) is naturally required for the purposes of life; and which, if noticed and properly attended to, would prove the most salutary monitor of health, and effectual preventive of disease. It is not the sense of satiety, for this is beyond the point of healthful indulgence, and is Nature's earliest indication of an abuse and overburden of her powers to replenish the system. It occurs immediately previous to this; and may be known by the pleasurable sensations of perfect satisfaction, ease, and quiescence of body and mind. It is when the stomach says, *enough*; and it is distinguished from satiety by the difference of sensations,—the latter saying *too much*." Every medical man is well aware how generally this rule is transgressed; some persons making a regular practice of eating to repletion; and others paying far too little attention to the preliminary operations, and thus ingesting more than is good for them, even though they may actually leave off with an appetite.

406. Although no universal law can be laid down for individuals, however, it is a matter of much practical importance to be able to form a correct *average* estimate. It is from the experience afforded by the usual consumption of food by large bodies of men, that our data are obtained; and these data are sufficient to enable us to predict with tolerable accuracy what will be required by similar aggregations, though they can afford no guide to the consumption of individuals.—We shall first consider the quantity sufficient for men in regular active exercise; and then inquire how far that may be safely reduced for those who lead a more sedentary life.—The Diet-scale of the British Navy may be advantageously taken as a specimen of what is required for the first class. It is well known that an extraordinary improvement has taken place in the health of seamen during the last 80 years; so that three ships can now be kept afloat with only the same number of men, which were formerly required for two. This is due to the improvement of the quality of the food, in combination

with other prophylactic means. At present, it may safely be affirmed that it would not be easy to construct a diet-scale more adapted to answer the required purpose. The health of crews that have been long afloat, and have been exposed to every variety of external conditions, appears to be preserved (at least when they are under the direction of judicious officers) to the full as well as that of persons subject to similar vicissitudes on shore; and there can be no complaint of insufficiency of food, although the allowance cannot be regarded as superfluous. It consists of from 31 to 35½ ounces of *dry* nutritious matter daily; of this 26 oz. are vegetable, and the rest animal. This is found to be amply sufficient for the support of strength; and considerable variety is produced, by exchanging various parts of the diet for other articles. This, however, is sometimes done erroneously; thus 8 oz. of fresh vegetables, which contain only 1½ oz. of solid nutriment, are exchanged for 12 oz. of flour, which is almost all nutritious. Sugar and Cocoa are also allowed, partly in exchange for a portion of the Spirits formerly served out; a further diminution of which has recently been effected, with great benefit.—A considerable reduction in this amount is of course admissible, where little bodily exertion is required, and where there is less exposure to low temperatures. In the case of Prisoners, the diet should of course be as spare as possible, consistently with health; but it should be carefully modified, in individual cases, according to several collateral circumstances, such as depression of mind, compulsory labour, previous intemperate habits, and especially the length of confinement. It has been supposed by some, that prisoners require a fuller diet than persons at large; this is probably erroneous; but more variety is certainly desirable, to counteract, as far as possible, the depressing influence of their condition upon the digestive powers. The evil effect of an undue reduction in the supply of food, and of insufficient attention to its quality, has unfortunately been too frequently displayed in our prisons; a notable example of which will be hereafter alluded-to (§ 419). A very excellent scale of dietaries adapted to the different conditions of prison-life, has been issued by the Government on the recommendation of the Inspector of Prisons.—The effects of confinement have been well shown in the experience of the Edinburgh House of Refuge, which was first established in 1832, for the reception of beggars during the Cholera, and which has been continued to the present time. The diet was at first a quart of oatmeal porridge for each person, morning and evening; and at dinner 1 oz. of meat, in broth, with 7 oz. of bread; making altogether about 23 oz. of solid food a day. During some months, this diet seemed to answer very well; the people went out fatter than they came in, owing to the diet being better than that to which they had been accustomed; but afterwards a proneness to disease manifested itself in those who had been residents there for a considerable time, and the diet was therefore somewhat increased, with good effect. The quantity of animal food was probably here too small; and the total weight might still have been sufficient, if it had been differently apportioned.—The inmates of Workhouses, especially those who have been accustomed to poor food during their whole lives, require much less than those more actively employed; and it is of importance that the diet should not be superior in quantity or quality, to that which the labouring classes in the respective neighbourhoods provide for themselves. In the Edinburgh workhouse, of which

the inmates usually have good health, they are fed upon oatmeal-porridge morning and evening, with barley-broth at dinner; the total allowance of dry nutriment is about 17 oz.; namely 13 oz. of vegetable, and 4 oz. animal. A series of Diet-scales for Paupers has been issued by the Poor-Law Commissioners, who state that these have all been employed in different parts of England, and have been found to work well; the average daily amount of solid aliment in these is only 25½ oz.; and of this not above 18 oz. would be *dry* nutriment.*

407. The smallest quantity of food upon which life is known to have been supported with vigour, during a prolonged period, is that on which Cornaro states himself to have subsisted. This was no more than 12 oz. a day, chiefly of vegetable matter, with 14 oz. of light wine, for a period of 58 years. There is only one instance on record, in which his plan was followed; and there are probably few who could long persevere in it, at least among those whose avocations require much mental or bodily exertion. It is certain, however, that life with a moderate amount of vigour may be preserved for some time, with a very limited amount of food; this appears from the records of shipwreck and similar disasters. In regard, however, to those who have been stated to fast for a period of months or even years, taking no nutriment, but maintaining an active condition, it may be safely asserted that they were impostors, probably possessing unusual powers of abstinence, which they took care to magnify (§ 422).

408. Of the quantity which *can* be devoured at one time, this is scarcely the place to speak; since such feats of gluttony only demonstrate the extraordinary capacity which the stomach may be made to attain by continual practice. Many amusing instances are related by Captain Parry in his Arctic Voyages; in one case, a young Esquimaux, to whom he had given (for the sake of curiosity) his full tether, devoured in four-and-twenty hours, no less than 35 lbs. of various kinds of aliment, including tallow candles. A case has more recently been published of a Hindoo, who can eat a whole sheep at a time; this probably surpasses any other instance on record. The half-breed *voyageurs* of Canada, according to Sir John Franklin, and the wandering Cossacks of Siberia, as testified by Capt. Cochrane, habitually devour a quantity of animal food, which would be soon fatal to any one unused to it. The former are spoken of as very discontented, when put on a short allowance of 8 lbs. of meat a day; their usual consumption being from 12 to 20 lbs.—That a much larger quantity of food than that formerly specified, may be habitually taken with perfect freedom from injurious consequences, under a particular system of exercise, &c., appears from the experience of those who are *trained* for feats of strength, pugilistic encounters, &c. The ordinary belief that the athletic constitution cannot be long maintained, appears to have no real foundation; nor does it appear that any ultimate injury results from the system being persevered-in for some time. That trained men often fall into bad health, on the cessation of the plan, is probably owing in part to the intemperance and other bad habits of persons of the class usually subjected to this discipline. The effects of trainers' regimen are hardness and firmness of the muscles, clearness of the skin, capability of bearing

* A copious collection of Dietaries will be found in Dr. Pereira's "Treatise on Food and Diet."

continued severe exercise, and a feeling of freedom and lightness (or "corkiness") in the limbs. During the continuance of the system, it is found that the body recovers with wonderful facility from the effects of injuries; wounds heal very rapidly; cutaneous eruptions usually disappear. Clearness and vigour of mind, also, are stated to be results of this plan.*

409. It is not enough for the healthy support of the body, that the Food ingested should contain an adequate proportion of alimentary constituents; it is important that these should be in a wholesome or undecomposing state. Putting out of view all impregnations with deleterious substances, which the articles used as food may have received from various external sources, it cannot be questioned that they may derive a poisonous character from changes taking place in their own nature and composition. Thus it is a fact very familiar to German Toxicologists, that cheese, bacon, sausages, and other articles, may spontaneously undergo such deleterious alterations, as give rise, when they are employed as food, to all the symptoms of irritant poisoning, which may even pass on to produce fatal consequences; that such occurrences are very rare in this country, is probably to be attributed to a difference in the mode of preparation. This change does not appear to consist in simple putrescence; for the effects which the cheese-poison, sausage-poison, &c., produce on the animal economy, are far more potent than mere putrescence could occasion; and it is supposed by Liebig to consist in the generation of a peculiar ferment, which the stomach is not able to decompose. Similar changes in ordinary flesh-meat seem to be sometimes consequent upon the previous existence of a diseased condition in the animal which furnished it. Many instances of this kind have been recorded;† and the risk is quite sufficient to justify a strict prohibition of the use of any such article.—That meat which is simply putrescent is to be considered as injurious *per se*, when habitually employed, is scarcely a matter of reasonable doubt. It is true that some nations are in the habit of keeping their meat until it is tainted, having a preference for it in that condition, which seems to have grown out of the supposed necessity for thus employing it (a preference which has its parallel among the epicures in our own country, who consider the *haut goût* essential to the perfection of their venison or woodcock). One of the most remarkable examples of this kind among a civilized people, is furnished by the inhabitants of the Färoe islands; who, according to the Report of Dr. Panum, who has investigated their Sanitary condition, live during a large part of the year upon meat in a state of incipient decom-

* The method of training employed by Jackson (a celebrated trainer of prize-fighters in modern times), as deduced from his answers to questions put to him by John Bell, was to begin on a clear foundation, by an emetic and two or three purges. Beef and mutton, the lean of fat meat being preferred, constituted the principal food; veal, lamb, and pork were said to be less digestible ("the last purges some men"). Fish was said to be a "watery kind of diet:" and is employed by jockeys who wish to reduce weight by sweating. Stale bread was the only vegetable food allowed. The quantity of fluid permitted was 3½ pints *per diem;* but fermented liquors were strictly forbidden. Two full meals, with a light supper, were usually taken. The quantity of exercise employed was very considerable, and such as few men of ordinary strength could endure.—This account corresponds very much with that which Hunter gave of the North American Indians, when about to set out on a long march.

† See "Ann. d'Hygiène," 1829, ii. p. 267; 1834, ii. 69; also Taylor in "Guy's Hospital Reports," April, 1843.

position, and introduce *rast*, or half-decayed maggotty flesh, fowl, or fish, as a special relish at the end of a meal.* The result of such a diet is (as might be anticipated) a continual disorder of the digestive organs, manifesting itself especially by diarrhœa. This is a symptom of annual occurrence on the bird-islands, and is also invariably observed after a large 'take' of whales, when much of the flesh of these animals necessarily becomes 'rast' before it is consumed. And this diarrhœa also complicates the course of other diseases, and even becomes, from its obstinacy and exhausting character, their most serious occurrence. Moreover, the Färoese are peculiarly liable to suffer severely from epidemics, when these are introduced among them; as was especially shown in the epidemic of Measles investigated by Dr. Panum, which attacked in the course of six months scarcely less than 6000 out of a population of 7782, no age being spared, and very few escaping, save such as had suffered from the malady in the epidemic which had occurred 65 years previously, and such as maintained a very rigorous isolation. Hence, notwithstanding that the usual rate of mortality is very low (only 1 in 64⅝ annually), it is obvious that there is a certain constitutional condition among them, which peculiarly favours the reception and propagation of Zymotic poisons; and it is quite conformable to the principles formerly laid down (§ 210), to attribute this to the habitual introduction of putrescent matter with the food. It is probable, indeed, that if it were not for the active lives of the Färoese, and their habitual exposure to a low external temperature, the direct effects of their diet would be far more prejudicial than they are; but a large part of these are probably neutralized by that activity of respiration which the habits of life of this hardy people induce, much of the noxious matter being decomposed and eliminated by the combustive process (§ 208). Hence it may well be conceived, that the effects of putrescent food would be much more decidedly manifested amongst individuals habitually living in close ill-ventilated apartments; and although the same means of comparison do not exist, since there is no part of our town-population habitually subsisting on such a diet as that of the Färoese, yet there is no want of evidence with regard to the injurious effects of even the occasional employment of putrescent food, especially when any zymotic disease is epidemic.†

* See Dr. Panum's 'Observations on an Epidemic of Measles in the Färoe Islands,' in the "Bibliothek for Lægr.," 1846; of which an analysis is given in the "Brit. and For. Med.-Chir. Rev.," vol. vii. p. 419.—Dr. Panum says, "During the interval of many months that the flesh, fish, or fowl, is neither fresh, nor yet wind-dried, it is called 'rast,' a word which I can only translate by half-rotten. This appellation it fully deserves from the horrible smell that it sends forth, from its mouldy aspect, and the numerous maggots that swarm upon it. I have seen a boat's crew of eight men, eating with great relish the raw flesh of the ca'aing whale, even though it was so decomposed that the smell of it was disagreeable to me even in an open boat, and the bottom of the boat was almost white with the maggots that fell from the decaying mass."

† Facts of this kind were abundantly furnished during the last visitation of Cholera. See the "Report of the General Board of Health on the Epidemic Cholera of 1848 and 1849," pp. 63, 64.—An instance of a very remarkable kind occurred at Bridgwater, towards the close of the epidemic, as related to the Author by Dr. Brittan. A cargo of spoiled oysters having been brought to the town, and the sale of them having been prohibited on account of their putrescent condition, they were given away to any who would receive them; and several children in a neighbouring school partook of them plentifully. In the course of the following night, all who had eaten of the oysters (so far as Dr. Brittan could ascertain) were attacked with cholera and choleraic diarrhœa, and eleven of the children died the next day.

410. That it is Water which constitutes the natural drink of Man, and that no other liquid can supply its place, is apparent from what has been already said of its uses in the system (§§ 74, 75); and it is only necessary here to remark, that the purity of the water habitually ingested is a point of extreme importance. A very minute impregnation with lead, for example, is quite sufficient to develope all the symptoms of chronic lead-poisoning, if the use of such water be sufficiently prolonged. In the case formerly referred to (§ 89), the amount of lead was only about 1 grain per gallon; and in a case subsequently published, in which also the symptoms of lead-poisoning were unequivocally developed, the amount was no more than 1-9th of a grain.* So again, an excess of the saline ingredients which appear to be innocuous in small quantities, may produce a marked disorder of the digestive organs, and (through them) of the system generally.† Moreover, as in the case of food, the presence of a very small amount of putrescent matter is quite sufficient to produce the most pernicious results, when that matter is habitually introduced into the system; and these results, on the one hand, manifest themselves in the production of certain disorders which appear distinctly traceable to the direct action of the poison so introduced; whilst, on the other, they become apparent in the extraordinary augmentation of the liability to attacks of such zymotic diseases as may at the time be prevalent.‡

411. The various beverages employed by Man for the most part consist of Water holding solid matters of different kinds in solution; and it is not requisite, therefore, to bestow any special attention upon them. But the use of *Alcohol*, in combination with water and with organic and saline compounds, in the various forms of 'fermented liquors,' deserves particular notice, on account of the numerous fallacies which are in vogue respecting it.—In the *first* place it may be safely affirmed, that Alcohol cannot answer any one of those important purposes for which the use of Water is required in the system; and that, on the other hand, it tends to antagonize many of those purposes, by its power of precipitating most of the organic compounds, whose solution in water is essential to their appropriation by the living body. *Secondly*, the ingestion of Alcoholic liquors cannot supply anything which is essential to the due nutrition of the system; since we find not only individuals, but whole nations, maintaining the highest vigour and activity, both of body and mind, without ever

* See "Medical Gazette," Sept. 20, 1850, p. 518.

† Of this a very instructive case which occurred at Wolverton, has been published by Mr. Corfe in the "Pharmaceutical Journal," July, 1848. So large a number of individuals were there attacked, after the use of water from a certain well for some months, with disorders bearing a strong general resemblance to each other, though differing in their subordinate features, and the intensity of these disorders bore such a constant ratio to the amount of the saline waters habitually employed, that no reasonable doubt could exist with respect to its causative agency. Yet the total quantity of saline matter was only about 40 grains per gallon, or but little more than one-sixth of that which is contained in the Marienbad water, the spa to which it presented the greatest resemblance in the combination of its components; and as the symptoms which were prevalent at Wolverton bore a very close correspondence with those which are known to result from the imprudent use of the Marienbad water, it appears that here too the same effects are produced by the long-continued employment of the weaker beverage, as by a much smaller number of doses of the stronger one.

‡ For ample evidence to this effect, see Dr. Pereira's "Treatise on Food and Diet," pp. 89-91; and the "Report of the General Board of Health on the Epidemic Cholera of 1848 and 1849," pp. 59-63, "Appendix A," p. 14, and "Appendix B," pp. 91-95.

employing them as an article of diet. *Thirdly*, there is no reason to believe that Alcohol, in any of its forms, can become directly subservient to the Nutrition of the tissues; for it may be certainly affirmed that, in common with non-azotized substances in general, it is incapable of transformation into Albuminous compounds; and there is no sufficient evidence that even Fatty matters can be generated in the body at its expense.* *Fourthly*, the alimentary value of Alcohol consists merely in its power of contributing to the production of Heat, by affording a *pabulum* for the respiratory process; but for this purpose it would be pronounced on Chemical grounds alone to be inferior to fat (§ 401); and the result of the experience of Arctic voyagers and travellers is *most decided* in regard to the low value of Alcohol as a heat-producing material.—*Fifthly*, the operation of Alcohol upon the living body is essentially that of a *stimulus;* increasing for a time, like other stimuli, the vital activity of the body, and especially that of the nervo-muscular apparatus, so that a greater effect may often be produced in a given time under its use, than can be obtained without it; but being followed by a corresponding depression of power, which is the more prolonged and severe in proportion as the previous excitement has been greater. Nothing, therefore, is in the end gained by their use; which is only justifiable where some temporary emergency can only be met by a temporary augmentation of power, even at the expense of an increased amount of subsequent depression; or where (as in the case of some individuals whose digestive power is deficient) it affords aid in the introduction of aliment into the system, which nothing else can so well supply. These cases, however, will be less numerous, in proportion as due attention is paid to other means of promoting health, which are more in accordance with Nature.—The Physiological objections to the habitual use of even small quantities of Alcoholic liquors, rest upon the following grounds. *First*, they are universally admitted to possess a *poisonous* character, when administered in large doses; death being the speedy result, through the suspension of nervous power which their introduction into the circulation, in sufficient quantity, is certain to induce.—*Secondly*, when habitually used in excessive quantities, universal experience shows that Alcoholic liquors tend to produce a morbid condition of the body at large, and especially of the nervous system; this condition being such as a knowledge of its *modus operandi* on the body would lead the Physiologist to predicate.—*Thirdly*, the frequent occurrence of more chronic diseases of the same character, among persons advanced in life who have habitually made use of Alcoholic liquors in 'moderate' amount, affords a strong probability that they result from a gradual perversion of the nutritive processes, of which that habit is the cause.—*Fourthly*, the special liability of the intemperate to zymotic diseases, indicates that the habitual ingestion of alcoholic liquors tends to prevent the due elimination of the products of the disintegration of

* It is quite true that some persons who consume large quantities of fermented liquors become very fat; but the material for this fat is probably derived in part from the constituents of the food, and in part from the disintegration of the tissues; the hydrocarbonaceous matters in the system being prevented from undergoing the combustive process to which they would otherwise be subject, by the superior affinity for oxygen which Alcohol possesses. Much of the fatty deposit in intemperate persons has the character of 'fatty degeneration;' the tendency to which is very marked in persons of this class.

the system, and thus to induce a 'fermentible' condition of the blood (§ 210). *Fifthly*, extended experience has shown that notwithstanding the temporary augmentation of power which may result from the occasional use of fermented liquors, the capacity for prolonged endurance of mental or bodily labour, and for resisting the extremes of heat and cold, as well as other depressing agencies, is diminished rather than increased by their habitual employment.—On these grounds, the Author has felt himself fully justified in the conclusion, that, for Physiological reasons alone, habitual abstinence from Alcoholic liquors is the best rule that can be laid down for the great majority of healthy individuals; the exceptional cases in which any real benefit can be derived from their use, being extremely few.*

## 2. *Of Hunger and Thirst;—Starvation.*

412. The want of solid aliment, arising out of the several sources of demand formerly enumerated (§§ 374-6), is indicated by the sensation of Hunger; and that of liquid by Thirst. The former of these sensations is referred to the stomach, and the latter to the fauces; but although certain conditions of these parts may be the immediate cause of the sensations in question, they are really indicative of the requirements of the system at large. For the intensity of the feelings bears no constant relation to the amount of solid or liquid aliment in the stomach; whilst, on the other hand, it does correspond with the excess of demand in the system, over the supply afforded by the blood; and it is caused to abate by the introduction of the requisite materials into the circulating fluid, even though this be not accomplished in the usual manner by the ingestion of food or drink into the stomach.

413. That the sense of Hunger, however, is *immediately* dependent upon some condition of the Stomach, seems to follow from the fact, that it may be temporarily alleviated, by introducing into the digestive cavity matter which is not alimentary. Of the precise nature of that condition, however, we have no certain knowledge. It is easy to prove that many of the causes which have been assigned for the sensation, are but little, if at all, concerned in producing it. Thus, mere emptiness of the Stomach cannot occasion it; since, if the previous meal have been ample, the food passes from its cavity some time before the uneasy feeling is renewed; and this emptiness may continue (in certain disordered states of the system) for many hours or even days, without a return of desire for food. Besides, the stomach may be filled with food, and yet Hunger may be intensely felt, if, from disease of the pylorus or any other cause, there be an obstacle to the passage of the aliment into the intestine, and to the completion of the processes of chylification and absorption, so that the system needs that which the digestive apparatus is unable to provide for it. Again, the sense of Hunger cannot be due, as some have supposed, to the action of the gastric fluid upon the coats of the stomach themselves; since this fluid is not poured into the stomach, except when the production of it is stimulated by the irritation of its secreting follicles. It is thought

* See his Prize Essay "On the Use and Abuse of Alcoholic Liquors in Health and Disease;" also the important Treatise on "Alcoholismus Chronicus" by Dr. Huss of Stockholm, of which an abstract is given in the "Brit. and For. Med.-Chir. Rev.," vols. vii. and ix.

y Dr. Beaumont, that the distension of these follicles with the secreted uid is the proximate cause of hunger; but there is no more reason to elieve, that the secretion of gastric fluid is accumulating during the ntervals when it is not required, than there is in regard to saliva, the chrymal fluid, or any other secretions, which are occasionally poured ut in large quantities under the influence of a particular stimulus; and, noreover, it is difficult to imagine how mental emotion, or any impression n the nervous system alone (which is able, as is well known, to dissipate he keenest appetite in a moment), can relieve such distension.—It may, erhaps, be a more probable supposition, that there is a certain condition f the Capillary circulation in the Stomach, which is preparatory to the ecretion, and which is excited by the influence of the Sympathetic nerves, hat communicate (as it were) the wants of the general system. This ondition may be easily imagined to be the proximate cause of the sensaion of hunger, by acting on the nervous centres.* When food is introluced into the stomach, the act of secretion is directly excited; the apillary vessels are gradually unloaded; and the immediate cause of the mpression on the nervous system is withdrawn.† By the conversion of he alimentary matter into materials fit for the nutrition of the system, he remote demand also is satisfied; and thus it is, that the condition of he stomach just referred-to, is permanently relieved by the ingestion of ubstances that can serve as food. But if the ingested matter be not of kind capable of solution and assimilation, or the digestive apparatus annot effect its preparation, the feeling of hunger is only temporarily elieved, and soon returns in greater force than before.—The theory here iven seems reconcilable with all that has been said of the conditions of he sense of Hunger; and particularly with what is known of the effect roduced upon it by nervous impressions, which have a peculiar influence pon the capillary circulation. It also corresponds exactly with what we now of the influence of the nervous system, and of mental impressions, pon other secretions (CHAP. XIV., SECT. 6).

414. The sense of Hunger, like other sensations, may not be taken ognizance of by the Mind, if its attention be strongly directed towards ther objects; of this fact, almost every one engaged in active occupaions, whether mental or bodily, is occasionally conscious. The nocturnal

* It was maintained by Brachet, that the senses of Hunger and Satiety are annihilated by ection of the Pneumogastric nerves; which, if true, would strongly confirm the view that e immediate source of these senses lies in the condition of the Stomach. But the researches f other experimenters, particularly those of Dr. John Reid ("Edinb. Med. and Surg. Journ.," pril, 1839, and "Physiological, Anatomical, and Pathological Researches," pp. 234–239), o not confirm this view; for they seem to show that after the immediate effect of the operaon has subsided, animals take food with no less avidity than previously. It appears, owever, from Dr. Reid's observations, as well as from those of Valentin, that the sense of tiety is more dependent upon the continuity of these nerves than that of Hunger; for imals on whom the section of the Pneumogastric has been performed, do not seem to know hen they have had enough, but continue to gorge themselves with food long after the omach has been adequately filled.

† These views are confirmed by the observations of M. Bernard on the condition of the stric follicles during the intervals of their functional activity. He states that when the omach is empty, the follicles are lined by cylindrical epithelium of the same kind as that hich covers the general surface of the gastric mucous membrane; and this even blocks up eir orifices, so that during fasting these appear as minute slightly prominent papillæ. The stric fluid is contained in newly-formed cells, which are rapidly generated and thrown off, hen the secreting process is called into renewed activity. ("Gaz. Méd.," Mars, 1844).

student, who takes a light and early evening meal, and, after devoting himself to his pursuits for several hours uninterruptedly, retires to rest with a wearied head and an empty stomach, but without the least sensation of hunger, is frequently prevented from sleeping by an indescribable feeling of restlessness and *deficiency;* and the introduction of a small quantity of food into the stomach will almost instantaneously allay this, and procure comfortable rest. Many persons, again, who desire to take active exercise before breakfast, are prevented from doing so by the lassitude and even faintness which it induces,—the bodily exercise increasing the demand for food, whilst it draws off the attention from the sensation of hunger.*

415. The conditions of the sense of Thirst appear to be very analogous to those of hunger. This sense is not referred, however, to the stomach, but to the fauces. It is generally considered that it immediately results from an impression on the nerves of the stomach; since, if liquids are introduced into the stomach through an œsophagus-tube, they are just as effectual in allaying thirst, as they are if swallowed in the ordinary manner. It may, however, be doubted whether the sense of thirst is not even more immediately connected with the state of the general system, than that of hunger; for the immediate relief afforded by the introduction of liquid into the stomach is fully accounted for, by the instantaneous absorption of the fluid into the veins, which is known to take place, when there is a demand for it, not only from Dr. Beaumont's observations, but from many experiments made with reference to this particular question. This demand is increased with almost equal rapidity, by an excess in the amount of the fluid excretions; and it may be satisfied, or at least alleviated, without the introduction of water into the stomach, this having been one of the results observed after the use of saline injections into the veins in cases of Asiatic Cholera, as well as after the immersion in a warm bath in cases of extreme dysphagia. Thirst may also be produced, however, by the impression made by peculiar kinds of food or drink upon the walls of the alimentary canal; thus salted or highly-spiced meat, fermented liquors when too little diluted, and other similarly irritating agents, excite thirst; the purpose of which is obviously to cause ingestion of fluid, by which they may be diluted.

* The Author may be excused from mentioning the following circumstance, which some years ago occurred to himself; and which seems to him a good illustration of the principle, that the sense of hunger *originates* in the condition of the general system, and that its *manifestation* through a peculiar action in the stomach, is to be regarded as a secondary phenomenon, —adapted, under ordinary circumstances, to arouse the mind to the actions necessary for the supply of the physical wants,—but capable of being overlooked, if the attention of the mind be otherwise directed. He was walking alone through a beautiful country, and with much to occupy his mind; and, having expected to meet with some opportunity of obtaining refreshment on his road, he had taken no food since his breakfast. This expectation, however, was not fulfilled; but, as he felt no hunger, he thought little of the disappointment. It was evening before he approached the place of his destination, after having walked about twenty miles, resting frequently by the way; and he then began to feel a peculiar lassitude, different from ordinary fatigue, which rapidly increased, so that during the last mile he could scarcely support himself. The "stimulus of necessity," however, kept him up; but on arriving at his temporary home, he immediately fainted. It is obvious that, in this case, the occupation of the mind on the objects around, and on its own thoughts, had prevented the usual warning of hunger from being perceived; and the effect which succeeded was exactly what was to be anticipated, from the exhaustion of the supply of food occasioned by the active and prolonged exertion.

416. The results of an entire deficiency of Food, or of its supply in a ıeasure inadequate for the wants of the system, constitute the phenomena f *Inanition* or *Starvation*. These have been experimentally studied by ı. Chossat* on Birds and Mammals; and the information thence gained ads us to a better comprehension of what is (unfortunately) too fre-uently exhibited in the Human subject.—The following were the general ymptoms noted by M. Chossat. The animals usually remain calm during ie first half or two-thirds of the period; but they then become more or ess agitated; and this state continues as long as their temperature remains levated. On the last day of life, however, whilst the temperature rapidly ılls, this restlessness ceases, and gives place to a state of stupor. The nimal, when set at liberty, sometimes looks round with astonishment, ithout attempting to fly; and sometimes closes the eyes, as if in a state f sleep. Gradually the extremities become cold, and the limbs so weak s no longer to be able to sustain the animal in a standing posture; it ılls over on one side, and remains in any position in which it may be laced, without attempting to move. The respiration becomes slower and lower; the general weakness increases, and the insensibility becomes ıore profound; the pupil dilates; and life becomes extinct, sometimes in calm and tranquil manner, sometimes after convulsive actions produc-ıg opisthotonic rigidity of the body. After the first day, in which the eces contain the residue of the food previously taken, their amount is ery small; and they seem to consist principally of grass-green biliary ıatter. Towards the close of life, they contain a much larger quantity water, even when none has been ingested by the animal; and include uch saline matter in addition to the biliary.—The average loss of weight ı the warm-blooded animals experimented-on by M. Chossat, between the ommencement of the period of Inanition and its termination by death, as 40 per cent; but he met with a considerable variation in the ex-emes, which seemed to depend chiefly on the amount of fat previously cumulated in the body; those animals losing most weight, in which the t had been most abundant, which were also those that lived the long-t.† Taking 40 per cent as the mean, M. Chossat obtained the following ırious results, as regards the relative diminution of the several tissues ıd organs of the body; those which lost *more* than the mean, being dis-uguished from those which lost *less*.

| Parts which lose *more* than 40 per cent. | | Parts which lose *less* than 40 per cent. | |
|---|---|---|---|
| ıt | 93·3 | Muscular coat of stomach | 39·7 |
| ood | 75·0 | Pharynx and œsophagus | 34·2 |
| leen | 71·4 | Skin | 33·3 |
| ıncreas | 64·1 | Kidneys | 31·9 |
| ver | 52·0 | Respiratory apparatus | 22·2 |
| eart | 44·8 | Osseous system | 16·7 |
| testines | 42·4 | Eyes | 10·0 |
| ıscles of Locomotion | 42·3 | Nervous system | 1·9 |

* "Recherches Expérimentales sur l'Inanition," Paris, 1843.

† There is a well-known case of a fat pig, which was buried in its sty for 160 days, under rty feet of the chalk of Dover cliff; and which was dug out alive at the end of that time, luced in weight from 160 lbs. to 40 lbs., or no less than 75 per cent. ("Trans. of Linn. c.," vol. xi. p. 411). The extraordinary prolongation of life in this case may be attributed the retention of the *heat* of the body by the non-conducting power of the chalk; and to the ention of its moisture by the saturation of the air in its immediate vicinity.

The points most worthy of note in the above table, are the almost complete removal of the *fat*, and the reduction of the *blood* to three-fourths its normal amount; whilst the nervous system undergoes scarcely any loss. It would seem, in fact, as if the supervention of death was coincident with the consumption of all the disposable combustive material; and that up to that point, the whole remaining energy of nutrition is concentrated upon the nervous system. And it will be shown hereafter (CHAP. XIII.), that there is adequate ground for considering death by *starvation* as really death by *cold;* since the temperature of the body is maintained with little diminution until the fat is thus consumed, and then rapidly falls, unless it be kept up by heat externally applied.—As might be expected from what has been already said of the rapidity of interstitial change at the earlier periods of life (§ 130), it was found by Chossat that the diurnal loss was much the most rapid in young animals, and that the duration of their lives when deprived of food was consequently far less than that of adults. He further ascertained that the results of *insufficient* alimentation were in the end the same as those of total deprivation of food; the total amount of loss being almost exactly identical, but its rate being less, so that a longer time was required to produce it. He did not find that much influence was exerted on the duration of life, by permitting or withdrawing the supply of water; but this statement does not apply to Man, in whom death supervenes much earlier when liquid as well as solid aliment is withheld; and the indifference in the case of Birds is probably due to the fact that they ordinarily drink very sparingly, and eliminate very little water in the various excretions.

417. The most prominent symptoms of Starvation, as they have been noted in the Human subject, are as follows:—In the first place, severe pain in the epigastrium, which is relieved on pressure; this subsides after a day or two, but is succeeded by a feeling of weakness and 'sinking' in the same region; and an insatiable thirst supervenes, which, if water be withheld, thenceforth becomes the most distressing symptom. The countenance becomes pale and cadaverous; the eyes acquire a peculiar wild and glistening stare; and general emaciation soon manifests itself. The body then exhales a peculiar fœtor, and the skin is covered with a brownish, dirty-looking, and offensive secretion. The bodily strength rapidly declines; the sufferer totters in walking, his voice becomes weak, and he is incapable of the least exertion. The mental powers exhibit a similar prostration; at first there is usually a state of stupidity, which gradually increases to imbecility, so that it is difficult to induce the sufferer to make any effort for his own benefit; and on this a state of maniacal delirium frequently supervenes. Life terminates either in the mode described in Chossat's observations, or, as occasionally happens, in a convulsive paroxysm.*—On post-mortem examination, the condition of the body is found to be such as the results of Chossat's obervations would indicate; namely, extreme general emaciation and disappearance of fat, diminution in the bulk of the principal viscera, and almost complete bloodlessness, save in the brain, which still receives its usual supply. It is specially worthy of note, that the coats of the small intestines are peculiarly thinned

* See Rostan in "Diction. de Médecine," art. 'Abstinence;' and Dr. Donovan's account of the Irish famine of 1847 in the "Dublin Medical Press," Feb., 1848.

'Donovan, loc. cit.), so that they become almost transparent; and that :he gall-bladder is almost invariably turgid with bile, the cadaveric exudation of which tinges the surrounding parts. And further, the body rapidly passes into decomposition.

418. Now it is peculiarly worthy of note, that the deficient supply of new histogenetic materials appears to check the elimination and removal of those which have become effete; for in no other way can we account for that tendency to putrescence, which is so remarkably manifested during life in the fœtid exhalation and in the peculiar secretion from the skin, and which is shown after death in the rapidity with which putrefaction supervenes. Moreover, towards the close of many exhausting diseases, the fatal termination of which is really due to a chronic inanition, it frequently happens that a 'colliquative diarrhœa' comes on, which must be considered as a manifestation of the general disintegration that is making progress even during life.—Now referring to the conditions formerly enumerated (§ 210), as those which favour the operation of zymotic poisons in the body, it is obvious that no state could be more liable to it than this; since we have not merely that general depression of the vital powers which is a predisposing cause of almost any kind of malady, and pre-eminently so of zymotic diseases; but also the presence of a large amount of disintegrating matter in the blood and general system, which forms the most favourable nidus possible for the reception and multiplication of such poisons. And thus it happens that pestilential diseases most certainly follow in the wake of a famine, and carry off a far greater number than perish from actual starvation.

419. Another class of phenomena, however, results from such a deficiency of alimentation as is not adequate to produce the results just described; provided this deficiency be prolonged for a considerable length of time, and especially if it be conjoined with other unfavourable conditions. Of this a remarkable example was presented at the Milbank Penitentiary in 1823. The prisoners confined in this establishment, who had previously received an allowance of from 31 to 33 oz. of dry nutriment daily, had this allowance suddenly reduced to 21 oz., animal food being at the same time almost entirely excluded. They were at the same time subjected to a low grade of temperature, and to considerable exertion; and were confined within the walls of a prison situated in the midst of a marsh which is below the level of the adjoining river. The prison had been previously considered healthy; but in the course of a few months, the health of a large proportion of the inmates began to give way. The first symptoms were loss of colour, and diminution of flesh and strength; subsequently diarrhœa, dysentery, and scurvy; and lastly adynamic fevers, or headache, vertigo, convulsions, maniacal delirium, apoplexy, &c. The smallest loss of blood produced syncope, which was frequently fatal; and after death, ulceration of the mucous lining of the alimentary canal was very commonly found. Out of 860 prisoners, no fewer than 437, or 52 per cent, were thus affected. The influence of concurrent conditions, especially of previous confinement, was here remarkably shown; for those were found to be most liable to disease, who had been in prison the longest. That the reduction of the allowance of food, however, was the main source of the epidemic, was proved by the two following facts:—the prisoners employed in the kitchen, who had 8 oz. of bread additional per

day, were not attacked, except three who had only been there a few days: and after the epidemic had spread to a great extent, it was found that the addition of 8 oz. to the daily allowance of vegetable food, and ½ oz. to the animal, greatly facilitated the operation of the remedies which were used for the restoration of health.*—Another very striking example of the effects of prolonged insufficiency of diet, has been furnished by the "Maison Centrale" of Nîmes; which is a large penitentiary containing an average of 1200 prisoners. The mortality in this prison, between the years 1829 and 1847, varied from 1 in 7·85 to 1 in 23·88, the average being 1 in 12·70; whilst the average mortality among the inhabitants of the town of Nîmes, of the same age and sex, was only 1 in 49·9; so that the mortality among the prisoners was from *two* to *six* times as great as that among the townspeople, the average being nearly *four* times. Several causes doubtless concurred to produce this terrible result; but whilst over-crowding and deficient ventilation were *constant*, deficiency of food, amount of labour exacted, and depression of temperature were *variable;* and the variations in the rate of mortality followed these last so uniformly, that there could be no doubt of their dependence upon them.†

420. It is a curious effect of insufficient nutriment, as shown by the inquiries of Chossat (Op. cit.), that it produces an incapability of digesting even the limited amount supplied. He found that, when turtle-doves were supplied with limited quantities of corn, but with water at discretion, the whole amount of food taken was scarcely ever actually digested; a part of it being rejected by vomiting, or passing off by diarrhœa, or accumulating in the crop. It seems as if the vital powers were not sufficient to furnish the requisite supply of gastric fluid, when the body began to be enfeebled by insufficient nutrition; or perhaps we might well say, the materials of the gastric fluid were wanting.—Hence the loathing of food, which is often manifested by those who have been subjected to the influence of an insufficient diet-scale in our prisons and poor-houses, and which has been set down to caprice or obstinacy, and punished accordingly, may be actually a proof of the deficiency of the supply, which we might expect to have been voraciously devoured, if really less than the wants of the system require.

421. It is extremely important that the Medical Practitioner should be aware, that many of the phenomena above described may be induced by the adoption of a system of too-rigid abstinence in the treatment of various diseases; and that they have been frequently confounded with the symptoms of the malady itself, and have led to an entirely erroneous method of treating it. "Many cases," says Dr. Copland,‡ "have occurred to me in practice, where the antiphlogistic regimen, which had been too rigidly pursued, was itself the cause of the very symptoms which it was employed to remove. Of these symptoms, the affection of the head and delirium are the most remarkable, and the most readily mistaken for an actual disease requiring abstinence for its removal."—The experience of those, especially, who are largely engaged in consulting practice, must have furnished numerous illustrations of the above statement. Dr. Copland

* See Dr. Latham "On the Diseases in the Milbank Penitentiary;" 1824.

† See the highly-instructive account of this series of occurrences, by M. Boileau-Castelnau, chief physician to the "Maison Centrale," in "Ann. d'Hygiène Publ.," Janv., 1849.

‡ "Dictionary of Practical Medicine," vol. i. p. 26.

mentions the following. "A professional man had been seized with fever, for which a too rigid abstinence was enforced, not only during its continuance, but also during convalescence. Delirium had been present at the height of the fever, and recurred when the patient was convalescent. A physician of eminence in maniacal cases was called to him, and recommended that he should be removed to a private asylum. Before this was carried into effect, I was requested to see him. A different treatment and regimen, with a gradual increase of nourishment, were adopted; and he was well in a few days, and within a fortnight returned to his professional avocations."

422. The time during which life can be supported under total abstinence from food or drink, is usually stated to vary from 8 to 10 days;* the period may be greatly prolonged, however, by the occasional use of water, and still more by a very small supply of food; or even, it would seem, by a moist condition of the surrounding atmosphere, which obstructs the exhalation of liquid from the body. Thus Foderé mentions that some workmen were extricated alive, after fourteen days' confinement in a cold damp vault, in which they had been buried under a ruin. Dr. Sloan has given an account† of the case of a healthy man æt. 65, who was found alive after having been shut up in a coal-mine for twenty-three days, during the first ten of which he was able to procure and swallow a small quantity of foul water; he was in a state of extreme exhaustion, and died three days afterwards, notwithstanding the attempts made to recover him. —It would seem as if certain conditions of the Nervous system, especially those attended with peculiar emotional excitement, are favourable to the prolongation of life under such circumstances. Thus, in a case recorded by Dr. Willan, of a young gentleman who starved himself under the influence of a religious delusion, life was prolonged for 60 days; during the whole of which time nothing else was taken than a little orange-juice. In a somewhat similar case which occurred under the Author's notice, in the person of a young French lady, more than 15 days elapsed between the time that she ceased to eat regularly, and the time of her being compelled to receive nourishment; during this period she took a good deal of exercise, and her strength seemed to suffer but little, although she swallowed solid food only once, and then in small quantity. Again, in certain states of the system commonly known as 'hysterical,' there is frequently a very remarkable disposition for abstinence, and power of sustaining it. In a case of this kind which occurred under the Author's own observation, a young lady, who had just before suffered severely from the tetanic form of Hysteria, was unable to take food for three weeks. The slightest attempt to introduce a morsel of solid matter into the stomach, occasioned violent efforts at vomiting; and the only nourishment taken during the period mentioned, was a cup of tea once or twice a day; and on many days not even this was swallowed. Yet the strength of the patient rather increased than diminished during this period; her muscles became firmer, and her voice more powerful.—It may be well to remark that, under such

* There seems adequate evidence that a state which may be characterized as one of *Syncope* may be prolonged for many days or even weeks, provided the temperature of the body be not too much reduced. This class of facts, however, will be more appropriately considered hereafter (CHAP. XIV., SECT. 7).

† "Medical Gazette," vol. xvii. p. 389.

circumstances, the continual persuasions of anxious friends are very injurious to the patient; whose return to her usual state will probably take place the earlier, the more completely she is left to herself.

### 3. *Movements of the Alimentary Canal.*

423. The motions by which Food is conveyed to the *Mouth* and introduced into its cavity, constituting the acts of *Prehension* and *Ingestion*, are ordinarily considered to be *voluntary*, at least in the adult; and it is indubitable that the Will has entire control over them. Nevertheless, they belong to that class of 'secondarily automatic' movements, whose character has been already noticed (§ 392); and like the movements of locomotion, may be kept up when the will is in abeyance, by the suggesting and guiding influence of sensations, thus being performed under the same essential conditions as the purely 'consensual' or 'sensori-motor' actions.* The necessity of guiding sensations for their performance is made evident by one of Sir C. Bell's experiments, the wrong interpretation of whose results originally led him to an erroneous view of the functions of the Fifth pair of nerves. He found that an Ass, in which the infra-orbital branch of this nerve had been divided, made no attempt to pick up oats with its lip, although the animal saw them, bent down its head with the obvious purpose of ingesting them, and brought its lip into absolute contact with them; hence he concluded that the power of *motion* was destroyed in the lip, when it was in reality only the *guiding sensation* that was deficient, the motor power being supplied by the Facial nerve or Portio dura.—But although the movements concerned in the ingestion of food in the adult require the co-operation of the sensorial centres, this is not the case with the act of *suction* in the Infant, which may be considered as essentially a *respiratory* act, and which is performed not merely without *will*, but even without *consciousness*. The experiments provided for us by nature, in the production of Anencephalous monstrosities, fully prove that the 'nervous circle' whereby the lips and respiratory organs are connected with the Medulla Oblongata, is alone sufficient for its performance; and Mr. Grainger has sufficiently established the same, by experiment upon puppies whose brain had been removed. He adds that, as one of these brainless puppies lay on its side, sucking the finger which was presented to its lips, it pushed out its feet in the same manner as young pigs exert theirs against the sow's dugs.†

* This, the Author thinks, will be conformable to the experience of most of his readers; who will find, if they analyze their own consciousness, that they continue to eat while their whole *attention* is given to some abstract train of thought, or to some external object. But a remarkable case will be cited hereafter (CHAP. XIV., Sect. 7), which fully confirms the view here advanced; the movements, not merely of the lips and jaws, but those by which food was conveyed to the mouth, having been carried on *automatically*, when once (so to speak) the spring was touched by which they were set in action.

† "Observations on the Structure and Functions of the Spinal Cord," pp. 80, 81.—The actions of the mammary fœtus of the Kangaroo, described by Mr. Morgan, furnish a very interesting exemplification of the same function of the Spinal Cord; this creature, resembling an earth-worm in appearance, and only about fourteen lines in length, with a brain corresponding in degree of development to that of a human fœtus of the ninth week, executes regular, but slow, movements of respiration, adheres firmly to the point of the nipple, and moves its limbs when disturbed. The milk is forced into the œsophagus by a compressor muscle, with which the mamma of the parent is provided. "Can it be imagined," very

The Human infant or other young Mammal, however, performs movements which are of a higher character than this; going in search, as it were, of the source of its nourishment; towards which it seems to be especially guided by the sense of Smell. Such movements are probably to be considered as 'consensual,' and as deriving their first stimulus from the internal feelings of hunger, whilst their direction is given by the guiding sensation which indicates the situation of the appropriate aliment. That no such actions are called into play by the same stimuli, after the expiry of the period during which the young Mammal is dependent upon its maternal parent for its nourishment, seems to indicate that the reactive power of the nervous centres on which they are dependent is only temporary, and that it ceases with the need for its exercise; the child *growing-out* (so to speak) of this automatic power, whilst it *grows-into* many new ones,—those especially, which are connected with the generative function.

424. The food thus introduced into the mouth, is subjected (unless it be already in a state which needs no further reduction) to the process of *Mastication.* This is evidently an operation of great importance in preparing the substances to be afterwards operated-on for the action of their solvent; and it exactly corresponds with the trituration to which the Chemist would submit any solid matter, that he might present it in the most advantageous form to a digestive menstruum. The complete disintegration of the alimentary matter is, therefore, of great consequence; and, if imperfectly effected, the subsequent processes are liable to derangement. Such derangement we continually meet with; for there is not, perhaps, a more frequent source of Dyspepsia than imperfect mastication, whether resulting from the haste with which the food is swallowed, or from the want of the instruments proper for the reducing operation. The mechanical disintegration of the food is manifestly aided by Insalivation; but the admixture of Saliva also exerts, as we shall hereafter see (§ 439), a very marked influence on the chemical composition of certain of its constituents.—The movements of Mastication, still more than those already adverted-to, although under the complete control of the Will, and originally dependent upon it for their excitation, come at last to be of so *habitual* a character, that they continue when the direct influence of the will is withdrawn, the influence of the 'guiding sensation,' however, being essential to their performance.* Every one is conscious that the act of mastication may be performed as well, when the mind is attentively dwelling on some other object, as when directed to *it;* but, in the former case, we are rather apt to go on chewing and rechewing what is already fit to be swallowed, simply because the will does not exert itself to check the action, and to carry the food backwards within the reach of the muscles of deglutition. This conveyance of food backwards to the fauces is a distinctly voluntary act; and it is necessary that it should be guided by the sensation, which there results from the contact it induces. If the

justly asks Mr. Grainger, "that in this case there are sensation and volition, in what can be proved anatomically to be a fœtus?"

* Thus, in the curious case formerly referred-to (§ 373 *note*), food can only be administered by carrying-back the spoon containing it, until it touches the fauces and thus excites an act of deglutition. Sensation being here entirely deficient, there is nothing to excite or to guide the movements of the muscles of the mouth and tongue.

surface of the pharynx were as destitute of sensation, as is the lower part of the œsophagus, we should not know when we had done what was necessary to excite its muscles to operation.—The muscles concerned in the Mastication of food are nearly all supplied by the third branch of the Fifth pair, a large proportion of which is well known to have a motor character. Many of these muscles, especially those of the cheeks, are also supplied by the Facial nerve; and yet, if the former be paralyzed, the latter cannot stimulate them to the necessary combined actions. Hence we see that the movements are of an associated character, their due performance being dependent on the part of the nervous centres, from which the motor influence originates.* If the Fifth pair, on the other hand, be uninjured, whilst the Portio Dura is paralyzed, the movements of Mastication are performed without difficulty; whilst those connected in any way with the Respiratory function, or with Expression, are paralyzed. If, again, the sensory portion of the Fifth pair be paralyzed, the act of Mastication is very imperfectly performed, even though the motor power be not in the least impaired; for the muscles cannot be made to perform the requisite associated movements, without the guidance of sensations; so that the morsel lodges between the teeth and the cheek, or beneath the tongue, and can with difficulty be kept in the appropriate position.

425. When the reduction of the food in the mouth has been sufficiently accomplished, it is carried into the *Pharynx*, and thence propelled down the œsophagus into the stomach, by a set of associated movements, which, taken together, constitute the act of *Deglutition*. These movements were first described in detail by Magendie; but his account requires some modification, through the more recent observations of Dzondi.†—The *first* stage in the process is the carrying-back of the food, until it has passed the anterior palatine arch; this, which is effected by the approximation of the tongue and the palate, is a purely voluntary movement. In the *second* stage, the tongue is carried still further backwards, and the larynx is drawn forwards under its root, so that the epiglottis is pressed-down over the rima glottidis. The muscles of the anterior palatine arch contract after the morsel has passed it, and assist its passage backwards; these, with the tongue, cut off completely the communication between the fauces and the mouth. At the same time, the muscles of the posterior palatine arch contract in such a manner, as to cause the sides of the arch to approach each other like a pair of curtains, so that the passage from

* Comparative Anatomy furnishes the key to these phenomena, which seem at first sight to be somewhat strange.—Among Invertebrate animals generally, the Respiratory organs are completely unconnected with the mouth; and a very distinct set of muscles is provided to keep them in action. These muscles have separate ganglia as the centres of their operations; and these ganglia are only connected indirectly with those of the sensori-motor system. The same is the case, in regard to the introduction of the food into the digestive apparatus. The muscles concerned in this operation have their own centres,—the Stomato-gastric and Pharyngeal ganglia, which are not very closely connected with the cephalic, or with the respiratory, or with those of general locomotion. Now in the Vertebrata, the distinct organs have been so far blended together, that the same muscles serve the purposes of both; but the different sets of movements of these muscles are excited by different nerves; and the effect of division of either nerve, is to throw the muscle out of connection with the function to which that nerve previously rendered it subservient,—as much as if the muscle were separated from the nervous system altogether.

† See Prof. Müller's "Elements of Physiology" (translated by Dr. Baly), p. 501.

the fauces into the posterior nares is nearly closed by them; and to the cleft between the approximated sides, the uvula is applied like a valve. A sort of inclined plane, directed obliquely downwards and backwards, is thus formed; and the morsel slides along it into the pharynx, which is brought-up to receive it. Some of these acts may be performed voluntarily; but the combination of the whole is automatic. The *third* stage of the process, the propulsion of the food down the œsophagus, then commences. This is accomplished, in the upper part, by means of the constrictors of the pharynx; and in the lower, by the muscular coat of the œsophagus itself. When the morsels are small, and are mixed with much fluid, the undulating movements from above downwards succeed each other very rapidly; this may be well observed in Horses whilst drinking; large morsels, however, are frequently some time in making their way down. Each portion of food and drink is included in the contractile walls, which are closely applied to it during the whole of its transit. The gurgling sound, which is observed when drink is poured down the throat of a person in *articulo mortis*, is due to the want of this contraction. The whole of the third stage is completely involuntary.—At the point where the œsophagus enters the stomach, the 'cardiac orifice' of the latter, there is a sort of sphincter, which is usually closed, but which opens when sufficient pressure is made on it by accumulated food, closing again, when this has passed, so as to retain it in the stomach.

426. The purely *automatic* nature of the act of Deglutition is shown by the fact, that no attempts on our own part will succeed in performing it really *voluntarily*. In order to excite it, we must supply some stimulus to the fauces. A very small particle of solid matter, or a little fluid (saliva, for instance), or the contact of the back of the tongue itself, will be sufficient; but without either of these, *we cannot swallow at will*. Nor can we restrain the tendency, when it is thus excited by a stimulus; every one knows how irresistible it is, when the fauces are touched in any unusual manner; and it is equally beyond the direct control of the will, in the ordinary process of eating,—voluntary as we commonly regard this. The only mode in which the will can influence it, is by regulating the approach of the stimulus necessary to excite it; thus, we voluntarily bring a morsel of food, or a little fluid, into contact with the surface of the fauces, and an act of deglutition is then involuntarily excited; or we may voluntarily keep all stimulus at a distance; and no effort of the will can then induce the action. Moreover, this action is performed, like that of respiration, when the power of the will is suspended, as in profound sleep, or in apoplexy affecting only the brain; and it does not seem to be at all affected by the entire removal of the brain, in an animal that can sustain the shock of the operation; being readily excitable, on stimulating the fauces, so long as the nervous structure retains its functions. This has been experimentally proved by Dr. M. Hall; and it harmonizes with the natural experiment sometimes brought under our notice in the case of an anencephalous infant, in which the power of swallowing seems as vigorous as in the perfect one. But, if the 'nervous circle' be destroyed, either by division of the trunks, or by injury of any kind to the portion of the nervous centres connected with them, the action can no longer be performed; and thus we see that, when the effects of apoplexy are extending themselves from the brain to the spinal cord, whilst the respiration becomes

stertorous, the power of Deglutition is lost, and then respiration also speedily ceases.

427. Our knowledge of the nerves specially concerned in this action is principally due to the very careful and well-conducted experiments of Dr. J. Reid.*—The distribution of the Glosso-pharyngeal evidently points it out as in some way connected with it; but this, when carefully examined, discloses the important fact, that the nerve scarcely sends any of its branches to the muscles which they enter, these mostly passing through them, to be distributed to the superjacent mucous surface of the tongue and fauces. Further, when the trunk is separated from the nervous centres, irritation produces scarcely any muscular movements. Hence it is not in any great degree an 'efferent' or motor nerve; and its distribution would lead us to suppose its chief function to be 'afferent;' namely, the conveyance of impressions from the surface of the fauces to the Medulla Oblongata. This inference is fully confirmed by the fact, that, so long as its trunk is in connection with the centre, and the other parts are uninjured, pinching, or other severe irritation of the Glosso-pharyngeal, will often excite distinct acts of deglutition. Such irritation, however, may excite only convulsive twitches, instead of the regular movements of swallowing; and it is evident that, here as elsewhere, the impressions made upon the extremities of the nerves are much more powerful excitors of reflex movement, than those made upon the trunk, though the latter are more productive of pain. It was further observed by Dr. Reid, that this effect was produced by pinching the pharyngeal branches only; no irritation of the lingual division being effectual to the purpose.—If, then, the muscles of deglutition be not immediately stimulated to contraction by the Glosso-pharyngeal nerve, it remains to be inquired, by what nerve the motor influence is conveyed to them from the Medulla Oblongata; and Dr. Reid was equally successful in proving, that this function is chiefly performed by the Pharyngeal branches of the Pneumogastric. Anatomical examination of their distribution shows, that they lose themselves in the muscles of the pharynx; and whilst no decided indications of suffering can be produced by irritating them, evident contractions are occasioned, when the trunk, separated from the brain, is pinched or otherwise stimulated.—It appears, however, that neither is the Glosso-pharyngeal the sole excitor nerve, nor are pharyngeal branches of the Pneumogastric the sole motor nerves, concerned in deglutition; for after the former has been perfectly divided on each side, the usual movements can still be excited, though with less energy; and, after the latter have been cut, the animal retains the means of forcing small morsels through the pharynx, by the action of the muscles of the tongue and neck. From a careful examination of the actions of deglutition, and of the influence of various nerves upon them, Dr. Reid drew the following conclusions:—The *excitor impressions* are conveyed to the Medulla Oblongata chiefly through the Glosso-pharyngeal, but also along the branches of the Fifth pair distributed upon the fauces, and probably along the superior Laryngeal branches of the Pneumogastric distributed upon the pharynx. The *motor influence* passes chiefly along the Pharyngeal branches of the Pneu-

* "Edinb. Med. and Surg. Journ.," vol. xlix.; and "Physiological, Anatomical, and Pathological Researches," CHAP. IV.

mogastric; along the branches of the Hypoglossal, distributed to the muscles of the tongue, and to the sterno-hyoid, sterno-thyroid, and thyro-hyoid muscles; along the motor filaments of the Recurrent laryngeals; along some of the branches of the Fifth, supplying the elevator muscles of the lower jaw; along the branches of the Facial, ramifying upon the digastric and stylo-hyoid muscles and upon those of the lower part of the face; and probably along some of the branches of the Cervical plexus, which unite themselves to the Descendens noni. It was further observed by Dr. Reid (Op. cit. pp. 258—260), that the stylo-pharyngeus muscle is usually thrown into contraction, when the roots of the Glosso-pharyngeal nerve are irritated; and this has also been noticed by Mayo, Volkmann, and others;* so that we are to consider the Glosso-pharyngeal as a motor nerve, in so far as that muscle is concerned.

428. When the food has been propelled downwards by the Pharyngeal muscles, so far as their action extends, its further progress through the *Œsophagus* is effected by a kind of peristaltic contraction of the muscular coat of the tube itself. This movement is not, however, due *only* to the *direct* stimulus of the muscular fibre by the pressure of the food, as it seems to be in the lower part of the alimentary canal; for Dr. J. Reid has found, by repeated experiment, that the continuity of the œsophageal branches of the Pneumogastric with the Medulla Oblongata, is necessary for the rapid propulsion of the food; so that it can scarcely be doubted, that an impression made upon the mucous surface of the œsophagus, conveyed by the afferent fibres of these nerves to their ganglionic centre, and reflected downwards along the motor fibres, is the real cause of the muscular contraction. If the Pneumogastric be divided in the rabbit, on each side, above the œsophageal plexus, but below the pharyngeal branches, and the animal be then fed, it is found that the food is delayed in the œsophagus, which becomes greatly distended. Further, if the lower extremity of the Pneumogastric be irritated, distinct contractions are seen in the œsophageal tube, proceeding from above downwards, and extending over the cardiac extremity of the stomach.—We have here, then, a distinct case of *reflex action without sensation*, occurring as one of the *regular associated movements* in the natural condition of the animal body; and it is very interesting to find this following upon a reflex action *with* sensation (that of the pharynx), and preceding a movement which is altogether unconnected with the Spinal Cord (that of the lower part of the alimentary canal). The use of sensation in the former case has been already shown (§ 424). The muscular fibres of the œsophagus are *also* excitable, though usually in a less degree, by *direct* stimulation; for it appears that, in some animals (the Dog, for example), section of the pneumogastric does not produce that check to the propulsion of the food, which it occasions in the Rabbit; and even in the Rabbit, as Dr. M. Hall has remarked,† the simple contractility of the muscular fibre occasions a distinct peristaltic movement along the tube, after its nerves have been divided; causing it to discharge its contents, when cut across. Such a movement, indeed, seems to take place in something of a rhythmical manner (that is, at short

* It seems not improbable that the discrepant results obtained by different experimenters on this point, are partly to be explained by differences in the distribution of the nerves in the several animals operated on.

† "Third Memoir on the Nervous System," § 201.

and tolerably regular intervals,) whilst a meal is being swallowed; but as the stomach becomes full, the intervals are longer, and the wave-like contractions less frequent.—That the action of the Cardiac sphincters is reflex, and is dependent upon the 'nervous circle' furnished by the Pneumogastric nerves and their ganglionic centres, would appear from the fact, that when the trunks of these nerves are divided, the sphincter no longer contracts, and the food regurgitates into the œsophagus. The re-opening of the cardiac orifices, on pressure from *within* (which is usually resisted by the sphincter, as in the acts of defecation, parturition, &c.), is one of the first of that series of reversed actions which constitutes the act of *Vomiting* (§ 431); and this is accompanied by a reversed peristaltic action of the œsophagus. The independence of these actions, one of another, and their relation to a common cause, is remarkably shown by the fact, that when vomiting takes place as a consequence of the injection of tartar emetic into the veins, the reversed peristaltic action of the œsophagus is performed even after its separation from the stomach.

429. The food, which, thus propelled along the œsophagus, enters the *Stomach* through its cardiac orifice in successive waves, is immediately subjected to a peculiar peristaltic movement, which has for its object to produce the thorough intermixture of the gastric fluid with the alimentary mass, and to separate the portion which has been sufficiently reduced, from the remainder. The fasciculi composing the muscular wall of the human stomach, are so disposed as to lessen its diameter in every direction; and whilst the cavity is empty, they are uniformly contracted, so as to reduce the organ to its smallest dimensions. When food is introduced, the contraction of the parietes as a whole still continues, to such a degree as to make them closely apply themselves to its surface; but the contraction of the individual fasciculi alternates with relaxation, in such a manner as to induce a great variety of motions in this organ, sometimes transversely, and at other times longitudinally. "These motions," remarks Dr. Beaumont, who has enjoyed a peculiar opportunity of observing them,* "not only produce a constant disturbance or *churning* of the contents of the stomach, but they compel them, at the same time, to revolve about the interior from point to point, and from one extremity to the other." In addition to these movements, there is a constant agitation of the stomach, produced by the respiratory muscles. The motions of the stomach itself are not performed on any very exact plan, and are much influenced by the character of the ingesta, the state of the general system, and by other circumstances. The following is the ordinary course, however, of the revolutions of the food. "After passing the œsophageal ring, it moves from right to left, along the small arch; thence through the large curvature, from left to right. The bolus, as it enters the cardia, turns to the left, passes the aperture, descends into the splenic extremity, and follows the great curvature towards the pyloric end. It then returns, in the course of the smaller curvature, makes its appearance again at the aperture in its descent into the great curvature, to perform similar revolutions. These revolutions are completed in from one to three minutes.

* See the "Case of Alexis St. Martin, with Observations and Experiments by Dr. Beaumont," republished in this country by Dr. Andrew Combe.—This patient had a large fistulous orifice in his stomach, remaining after a wound which had laid open the cavity; but his general health had been completely restored.

They are probably induced in a great measure, by the circular or transverse muscles of the stomach. They are slower at first, than after chymyfication has considerably advanced;" at which time also there is an increased impulse towards the pylorus. It is probable that, from the very commencement of chymification, until the organ becomes empty, portions of chyme are continually passing into the duodenum; for the bulk of the alimentary mass progressively diminishes, and this the more rapidly as the process is nearer its completion. The accelerated expulsion appears to be effected by a peculiar action of the transverse muscles; and especially of that portion of them, which surrounds the stomach at about four inches from its pyloric extremity. This band is so forcibly contracted in the latter part of the digestive process, that it almost separates the two portions of the stomach into a sort of hour-glass form; and Dr. B. states that, when he attempted to introduce a long thermometer-tube into the pyloric portion of the stomach, the bulb was at first gently resisted, then allowed to pass, and then grasped by the muscular parietes beyond, so as to be drawn in: whence it is evident that the contraction has for its object, to resist the passage of solid bodies into the pyloric extremity of the stomach, at this stage of digestion, whilst the matter which has been reduced to the fluid form is pumped away (as it were) by the action of that portion of the viscus. These peculiar motions continue, until the stomach is perfectly empty, and not a particle of food or chyme remains; and when they are nearly brought to a close, the contraction of the pyloric orifice also gives way, to an extent sufficient to allow not only the undigested residue of the food, but also large solid bodies that may have been swallowed (such as coins and the like), to pass into the intestinal canal.

430. With regard to the degree in which these movements of the Stomach, whose share in the Digestive operation is so important, are dependent upon the Spinal cord, and are consequently of a 'reflex' nature, it is difficult to speak with certainty, owing to the contradictory results obtained by different experimenters. These contradictions, however, seem partly due to a diversity in the nature of the animals experimented on, and partly to a difference in the stage of the digestive process at which the observations were made. It seems to be well established, by the researches of Reid, Valentin, and others,* that distinct movements may be excited in the Stomach of the Rabbit, if distended with food, by irritating the Pneumogastric soon after the death of the animal; these movements seem to commence from the cardiac orifice, and then to spread themselves in a sort of peristaltic manner along the walls of the stomach; but no such movements can be excited if the stomach be empty. Various experiments upon living animals have led to a similar conclusion; food taken-in shortly before or subsequently to its division, having been found to be only dissolved on the surface of the mass, where it was in contact with the mucous membrane. But these experiments have been made for the most part upon Herbivorous animals, such as horses, asses, and rabbits; whose food is bulky and difficult of solution, requiring to be

* See Dr. Reid's "Physiological, Anatomical and Pathological Researches," chap. v.; Valentin "De Functionibus Nervorum Cerebralium," &c. chap. xi.; also Longet "Anatomie et Physiologie du Système Nerveux," tom. i. p. 323; and Bischoff in "Müller's Archiv.," 1843.

constantly changed in its position, so that every part of it may be successively brought to the exterior. On the other hand, Dr. Reid found, in his experiments upon Dogs, that, after the first shock of the operation had gone off, solution of food in the stomach, and absorption of chyle, might take place; and hence it may be inferred, that no influence of this nerve upon the muscular parietes of the stomach is essential to digestion in that species. This conclusion harmonizes well, therefore, with the fact already stated respecting the absence of such influence in the lower parts of its œsophagus; and it may, perhaps, be explained by the consideration, that the natural food of the dog is much less bulky and more easy of solution, than that of the animals already named; so that there is not so much need of that peculiar movement, which is in them so important an aid to the process of reduction.—There is yet much to be learned on this subject, however; especially in regard to the degree in which the movements may be checked or altered, by impressions transmitted through the nervous system. It was stated by Brachet, that, in some of his experiments upon the Pneumogastric, some hours after section of the nerve on both sides, the surface only of the alimentary mass was found to have undergone solution, the remainder of the mass remaining in the condition in which it was at first ingested; and if this statement can be relied on, it would appear that the movements of the stomach, like those of the heart, can be readily affected by a strong nervous impression. It may be partly in this manner, therefore, and not by acting upon the secretions alone, that strong Emotions influence the digestive process, as they are well known to do. On the other hand, the moderate excitement of pleasurable emotions may be favourable to the operation; not only by giving firmness and regularity to the action of the heart, and thence promoting the circulation of the blood, and the increase of the gastric secretion; but also in imparting firmness and regularity to the muscular contractions of the stomach.

431. Much discussion has taken place upon the question, how far contraction of the parietes of the Stomach itself actively participates in the operation of *Vomiting;* and many experiments have been made to determine the facts of the case. Some, as Magendie, have gone so far as to affirm that the stomach is entirely passive; grounding this inference upon the fact experimentally ascertained, that when the stomach was removed, and a bladder was substituted for it, this was emptied of its contents, by the compression of the parietes of the abdomen, when tartar emetic was injected into the veins. But this fact by no means disproves the active co-operation of the stomach; and judging from the analogy of the uterus, bladder, and rectum,—whose muscular walls are all actively concerned in the expulsion of their contents, though that expulsion is in great part due to the contraction of the abdominal muscles,—we should be led to concur with the common opinion, of which our own sensations during the act would indicate the correctness. And this opinion has been confirmed by observation of a case,* in which, the abdominal parietes having been accidentally laid open in the human subject, and the stomach having wholly protruded itself, it was seen to contract itself repeatedly and forcibly, during the space of half an hour, until by its own efforts it had expelled all its contents except gases. As already mentioned, the relaxation of the

* Lepine in "Bullet. de l'Acad. Roy. de Médecine," 1844.

cardiac sphincter is essential to the act of vomiting; and unless this take place, all the other movements will be in vain; for its fibres, when contracted, can resist the combined force of all the expulsor muscles. There can be little doubt that the violent but fruitless efforts at vomiting which we occasionally witness (two or three such efforts frequently preceding the effectual one), are prevented from emptying the stomach by the obstinacy with which the cardiac sphincter is kept closed; just as the expiratory effort which assists in emptying the stomach, is prevented, by the firmness with which the glottis is held shut, from expelling the contents of the chest. It is not true, as was formerly supposed, that the diaphragm actively co-operates in the effort of vomiting; for, as was first pointed out by Dr. M. Hall,* this effort, like those of defecation, urination, and parturition, is essentially performed by the muscles of expiration; with this difference, however, that the diaphragm, instead of being *passive,* is fixed, and supplies a firm surface against which the stomach is pressed. In this, as in the other cases just referred-to, the expulsive effort is preceded by a deep inspiration, after which the glottis is spasmodically closed during its whole continuance.—The immediate causes of vomiting may be reduced to three different categories. 1st. The contact of irritating substances with the mucous membrane of the stomach itself; these, however, cannot act upon more than its muscular coat by *direct* stimulation; and their operation upon the associated muscles must take place by *reflexion,* through the 'nervous circle' furnished by the pneumogastrics and the motor nerves of expiration. 2nd. Irritations applied to other parts of the body, likewise operating by *simply-reflex* transmission; as in the vomiting which is consequent upon the strangulation of a hernia, or the passage of a renal calculus; or in that which is excited by the injection of tartar emetic or emetin into the circulating current, where these substances probably produce their characteristic effect by their operation on the nervous centres. 3rd. Impressions received through the *sensorial* centres, which may be either sensational or emotional, but which do not operate unless they are *felt.* In this mode seems to be excited the vomiting that is induced by tickling the fauces, which first gives rise to the sensation of nausea; as well as the vomiting consequent upon disgusting sights, odours, or tastes, and upon those peculiar internal sensations which are preliminary to 'sea-sickness.' The recollection of these sensations, conjoined with the emotional state which they originally excited, may itself become an efficient cause of the action, at least in individuals of peculiarly irritable stomachs or of highly sensitive nervous systems; for this plays downwards upon the sensorial centres, in such a manner as to excite in them the same condition, as that which was originally produced through the medium of the sensory nerve, when the object was actually present. (See CHAP. XIV., SECT. 3.)

432. The passage of the Chyme, or product of the gastric digestion, through the pyloric orifice, into the commencement of the *Intestinal tube,* is at first slow; but when the digestive process is nearly completed, it is transmitted in much larger quantities. The pyloric orifice, like the cardiac, is furnished with a sphincter muscle; but how far its contractions are dependent upon 'reflex action,' has not yet been ascertained. The ingested matter, which undergoes further changes of a very important

* "Quarterly Journal of Science," vol. xxv. p. 388, et seq.

character within this portion of the canal, is gradually propelled onwards by the peristaltic contractions of its walls; and these are excited by the contact, either of the products of digestion, or of the secretions poured-in by the various glands that discharge their products into the intestinal tube.* In its progress along the small intestines, the nutritious portion of the ingested matter is gradually taken-up by the blood-vessels and absorbents; and the residue, combined with excrementitious matters separated from the blood, begins to assume the fæcal character. A further absorption takes place during the passage of the fæcal matter through the large intestines; and thus by the time it reaches the rectum, it has acquired a considerable degree of consistency.—The ordinary Peristaltic movements of the Intestinal canal are fully accounted-for, by referring them to the contractility of the muscular portion of its walls, called into action by direct stimulation (§ 316); and that they are not in any degree dependent upon nervous connection with the Cerebro-spinal centres, is clearly shown by their continuance after the destruction of these. Some Physiologists suppose that these movements are attributable to 'reflex' action, through a nervous circle furnished by the fibres and ganglia of the Sympathetic system. This supposition, however, is entirely unnecessary; since the Hallerian doctrine of independent irritability, of the truth of which such cogent evidence has been adduced (§§ 325—327), affords an adequate explanation of them. And it will be found, on careful examination, to have no sufficient evidence in its favour; the utmost which experiment can show, being that contractions *may be* excited through the medium of the Sympathetic nerves. But the experiments of Valentin, who, more than any other Physiologist, has succeeded in obtaining positive results of this kind, also indicate that the motor influence does not originate in the Sympathetic ganglia, but is derived from the Spinal cord.† The following are his general results, so far as they apply to this part of the subject.—The lower part of the Œsophagus in the neck is made to contract peristaltically from above downwards, by irritation of the roots of the first three cervical Spinal nerves, and of the cervical portion of the Sympathetic, through which last the former evidently operate. The thoracic portion of the œsophagus is made to contract, by irritation of the lowest Sympathetic ganglion of the neck, and of the higher thoracic ganglia, and also of the roots of the lower cervical Spinal nerves.—Muscular contractions of the Stomach are produced, by irritation of the roots of the 4th, 5th, 6th, and 7th cervical nerves, and of the first thoracic in the rabbit; so that a distinct furrow is evident between the cardiac and pyloric portion of the viscus; and the lower the nerve is irritated, the nearer to the pylorus do the contractions extend. Irritation of the first thoracic ganglion of the Sympathetic produces the same effect.—Contractions of the Intestinal tube, varying in place according to the part of the Spinal cord experimented-on,. may be excited by irritation of the roots of the dorsal, lumbar, and sacral nerves, and of the trigeminus; and similar effects are produced by irritation of the lower part of the thoracic portion,

* The Bile seems to have an important share in producing this effect; since, when the ductus choledochus is tied, constipation always occurs. The purgative action of Mercurials seems to depend in great part upon the increase of the hepatic and other secretions which it induces.

† "De Functionibus Nervorum Cerebralium et Nervi Sympathici," book ii. chap. 2.

of the lumbar, and of the sacral portions of the Sympathetic,—also of the splanchnic, and of the gastric plexus.

433. From these facts it is evident, that the movements of the Intestinal tube may be *influenced by* the Spinal Cord; and that what is commonly termed the Sympathetic nerve, is the channel of that influence, by the fibres which it derives from the Spinal system. But it by no means thence follows, that the ordinary peristaltic actions of the muscles in question are *dependent* on a stimulus reflected through the spinal cord, rather than on one directly applied to themselves. It is clear that, although these movements are of the first importance to the welfare of the system, such means of sustaining them are feeble, compared to those which we find provided for the maintenance of the distinctly-reflex actions of deglutition, respiration, &c. And the fact that they are capable of being at all times more easily excited by stimuli applied to the muscles, than by any kind of irritation applied to their nerves,—taken in connection with the fact that the muscles not only remain irritable, but will execute regular peristaltic contractions, for a long time after any such contractions can be excited through their nerves,—seems a very strong indication that nervous influence is not the ordinary agent in calling these movements into play. On the other hand, we do know that the peristaltic movements are affected by particular states of mind, or by conditions of the bodily system; and the connection just traced satisfactorily accounts for this, and is itself sufficiently explained.—The Intestinal tube, then, from the stomach to the rectum, is not dependent upon the Nervous Centres either for its contractility, or for its power of exercising it, but is enabled to propel its contents by its own inherent powers; still we find that here, as in other instances, the nervous centres exert a general control over even the Organic functions, doubtless for the purpose of harmonizing them with each other, and with the conditions of the organs of Animal life.

434. On examining the outlet by which the fæces are voided, we find that it is placed, like the entrance, under the guardianship of the Spinal Cord; subject, however, to some control on the part of the Will. In the lowest animals, the act of discharging excrementitious matter is probably as involuntary as are the acts immediately concerned in the introduction of nutriment; and it is performed as often as there is anything to be got rid of. In the higher classes, however, such discharges are much less frequent; and reservoirs are provided, in which the excrementitious matter may accumulate in the intervals. The associated movements required to empty these, are completely involuntary in their character; and are excited by the quantity, or stimulating quality, of the contents of the reservoir. But, had volition no control over them, great inconveniences would ensue; hence sensation is excited by the same stimulus which produces the movements, in order that, by arousing the will, the otherwise involuntary motions may be restrained and directed.—There can be little doubt, from the experiments of Dr. M. Hall, as well as from other considerations, that the associated movements, by which the contents of the rectum (and bladder) are discharged, correspond much with those of Respiration; being in their own nature excito-motor, but being capable of a certain degree of voluntary restraint and assistance. The act of Defecation (as of Urination) chiefly depends upon the combined contraction of

the abdominal muscles, similar to that which is concerned in the expiratory movement; but, the glottis being closed so as to prevent the upward motion of the diaphragm, their force acts only on the contents of the abdominal cavity; and so long as the sphincter of the cardia remains closed, it must press downwards upon the walls of the rectum and bladder,—the contents of the one or the other of these cavities, or of both, being expelled, according to the condition of their respective sphincters. These actions are doubtless assisted by the contraction of the walls of the rectum and bladder themselves; for we sometimes find their agency sufficient to expel the contents of the cavities, when there is a total paralysis of the ordinary expulsors, provided that the sphincters be at the same time sufficiently relaxed. This is more especially the case, when their power is augmented by increased nutrition. For example, in many cases of disease or injury of the Spinal Cord, the bladder ceases to expel its contents, through the interruption of the circle of reflex actions; but after a time, the necessity for drawing off the urine by the catheter is found to exist no longer, the fluid being constantly expelled as soon as it has accumulated in small quantities. In such cases, the mucous coat is found after death to be thickened and inflamed; and the muscular coat to be greatly increased in strength, and contracted upon itself. It would seem, then, that the abnormal irritability of the mucous membrane, and the increased nutrition of the muscular substance which appears consequent upon it, enable the latter to expel the urine without the assistance of the ordinary expulsors.

435. On the other hand, the sphincters which antagonize the expellent action, are usually maintained in a state of moderate contraction, so as to afford a constant check to the egress of the contents of the cavities; and this condition has been fully proved by Dr. M. Hall, to result from their connection with the Spinal Cord, ceasing completely when this is interrupted. But the sphincters are certainly in part controlled by the will, and are made to act in obedience to the warning given by sensation; and this voluntary power is frequently destroyed by injuries of the Brain, whilst the Spinal Cord remains able to perform all its own functions, so that discharge of the urine and fæces occurs.—In their moderate action, the expulsors and the sphincters may be regarded as balancing one another, so far as their reflex action is concerned; the latter having rather the predominance, so as to restrain the operation of the former. But, when the quantity or quality of the contents of the cavity gives an excessive stimulus to the former, their action predominates, unless the will be put in force to strengthen the resistance of the sphincter; this we are frequently experiencing, sometimes to our great discomfort. On the other hand, if the stimulus be deficient, the will must aid the expulsors, in order to overcome that resistance which is due to the reflex contraction of the sphincters; of this also we may convince ourselves, when a sense of propriety, or a prospective regard to convenience, occasions us to evacuate the contents of the rectum or bladder without a natural call to do so.

### 4. *Of the Changes which the Food undergoes, during its passage along the Alimentary Canal.*

436. The object of the Digestive process, as already pointed out, is to reduce the Alimentary matters to a condition in which they can be intro-

duced by Absorption into the Circulating system. This reduction is partly effected, as we have seen, by Mechanical means; but it is chiefly due to the chemical agencies which are brought to bear upon the ingested substances during their transit through the mouth, the stomach, and the upper portion of the intestinal tube. The first of these is exerted by the *Salivary* fluid, which is incorporated with the food in the act of mastication, and of which a large quantity descends with it to the stomach. For the secretion of this fluid, it will be remembered that three pairs of glands of considerable size are provided; namely, the parotid, the sublingual, and the submaxillary. But in addition to these, a very important part of the fluid is furnished by the numerous follicular glands lodged in and beneath the buccal mucous membrane. The Salivary glands are constructed upon that follicular type of which an example has been already given from the glands of Brunner (§ 234); their ultimate follicles (Fig. 91) are very minute (their average diameter being only about 1-1200th of an inch), and are closely surrounded by a plexus of capillary blood-vessels (Fig. 26). Their development commences from a simple canal, sending off bud-like processes, which opens from the mouth, and lies amidst a cellular blastema; and as their evolution advances, the large parent-cells of this blastema form communications with the gland-canal, which is at the same time extending its ramifications, and remain as the terminal follicles of these.

Fig. 91.

Lobule of *Parotid Gland* of a new-born Infant, injected with mercury. Magnified 50 diameters.

437. The inquiry into the chemical constitution and properties of the Saliva has for the most part been limited to the fluid obtained from the mouth, rather than to that secreted by the glands. The specific gravity of this fluid is usually (according to Lehmann) from 1004 to 1006; but it may rise to 1008 or 1009, or may sink to 1002, without any indication of coexisting disease. When examined microscopically, the Saliva is found to contain a small number of minute corpuscles derived from the Salivary glands, and large epithelial-scales thrown off by the buccal mucous membrane. Its reaction is usually alkaline, that of the Saliva furnished by the principal glands being always so (in the state of health), whilst that of the buccal mucous membrane is acid; so that when the former predominates, as is always the case when food is being masticated and digested, the saliva of the mouth is alkaline; whilst, when the latter is more abundant, as is often the case during the intervals of digestion, from the slow rate at which the salivary glandulæ then pour forth their product, the buccal saliva is frequently acid.—The following are two of the most recent analyses of this fluid that have been made; the one by the eminent chemist Frerichs,* whose contributions to the Physiology of Digestion are among the most valuable of the results which have been furnished by recent inquiries in this

* "See "Canstatt's Jahresbericht," 1850, p. 136; and "Wagner's Handwörterbuch," Art. 'Verdauung.'

direction; and the other by Dr. Wright ("Lancet," March, 1842), who has made a special study of the Salivary secretion.

*Dr. Wright.*

| | |
|---|---|
| Water | 988·10 |
| Solid Matters | 11·90 |
| Ptyaline | 1·80 |
| Mucus and epithelium | 2·60 |
| Fatty matter | ·50 |
| Albumen with soda | 1·70 |
| Sulphocyanide of potassium | ·90 |
| Alkaline and Earthy salts | 3·20 |
| Loss | 1·20 |
| | 100·00 |

*Dr. Frerichs.*

| | |
|---|---|
| Water | 994·10 |
| Solid Matters | 5·90 |
| Ptyaline | 1·41 |
| Mucus and epithelium | 2·13 |
| Fatty matter | ·07 |
| Sulphocyanide of potassium | ·10 |
| Alkaline and Earthy Chlorides, Phosphates; Oxide of iron | 2·19 |
| | 100·00 |

The total proportion of solid matter, as the analyses show, is subject to great variation; it commonly ranges between 7 and 12 parts in 1000, but may even reach 16 parts. We shall presently see, however, that this variation may be partly attributed to a difference in the proportions of the fluid poured into the mouth by the several glands which secrete it.—The substance to which the designation of *Ptyalin* is given, is that on whose presence the peculiar properties of the Saliva appear to depend; and it appears, as regards its chemical nature, to be an albuminous compound, in such a state of change, however, that it acts the part of a 'ferment.'*—The presence of Sulpho-cyanogen is interesting, not only because this is the only animal product in which this substance is known to occur, but because the uniformity with which it makes its appearance when searched-for, would seem to indicate that it performs some peculiar part in the operations to which the salivary fluid is subservient. Moreover, in a medico-legal point of view, the existence of a sulphocyanide in the saliva has a special importance; since, if in a state of sufficient concentration, it causes the saliva to exhibit the same blood-red colour, when treated with a per-salt of iron, as that which is produced by meconic acid. (The difference between the two, however, is easily made apparent, by adding a solution of perchloride of mercury; for this causes the colour produced by the sulphocyanide to disappear, whilst it has no action on that which is due to the presence of meconic acid.)—The Salts of the Saliva, with the exception of the foregoing, seem to correspond closely with those of the blood; and its alkaline reaction appears due, not to the presence of a free alkali, but to that of the basic phosphate of soda. The 'tartar' which collects on the teeth consists principally of the earthy phosphates, which are held together by about 20 per cent of animal matter; and the same may be said of the salivary concretions which occasionally obstruct the ducts.*

* The following, according to Prof. Lehmann (Lehrbuch der physiologischen Chemie," band ii. p. 15), are the distinctive chemical characters of ptyalin. Being held in solution by an alkali, the addition of a little acetic acid occasions a flocculent precipitate, which readily dissolves in an excess of the acid. When boiled with hydrochlorate of ammonia or sulphate of magnesia, the alkaline solution of ptyalin becomes very turbid; it is precipitated by tannic acid, bichloride of mercury, and basic acetate of lead; but not by alum, sulphate of copper, &c. The acetic acid solution is strongly precipitated on the addition of ferrocyanide of potassium; and when boiled with nitric acid, it yields a yellow solution. By these reactions it is shown that ptyalin closely resembles both albumen and casein, without being identical with either of them.

438. From the experiments of MM. Magendie* and Cl. Bernard,† however, on the secretions of the respective glands, as obtained directly from themselves by tubes passed into their ducts, it appears that their composition and physical characters are by no means uniform. For the fluid of the parotid and sublingual glands is clear, and as limpid and thin as water, and contains but a small proportion of solid matters (not more than 0·47 per cent in the dog, and 0·76 per cent in the horse, according to Lehmann and Jacubowitsch); whilst the fluid of the submaxillary is thick and viscid, resembling in colour and consistence ordinary simple syrup, and containing a far larger amount of solid matters, in which the organic components, however, bear a smaller proportion to the salts, than they do in the fluid of the other two glands. Now it has been observed by Bernard, that the flow of saliva which takes place during mastication proceeds almost entirely from the parotid and sublingual glands; whilst, during the act of deglutition, when the tongue carries the bolus back into the pharynx, the secretion of the submaxillary is the greatest. Hence it seems reasonable to conclude, that the purpose of these secretions is not identical; that of the parotid and sublingual being to saturate the food when mixed up with it in the act of mastication; whilst that of the submaxillary seems rather destined to facilitate deglutition.‡—The fluid which is secreted by the three principal glands, moreover, appears (from the experiments of Magendie and Bernard) to be far less efficacious than is the buccal saliva, in producing that chemical change in the food which it is the peculiar attribute of this secretion to exert (§ 439); whence it seems fair to conclude that the 'ferment' to which this change is due, is chiefly furnished by the smaller buccal glandulæ.—Of the quantity of Saliva which is secreted daily, it is impossible to form an exact estimate, since it varies greatly with the character of the food ingested, and the frequency with which that food is taken; the secreting process being, indeed, almost suspended when the masticator muscles and tongue are completely at rest, unless excited by a nervous stimulus. The taste, the sight, or even the idea, of savoury food, is sufficient to cause a flow of saliva, especially after a long fast; but it is by the masticatory movements that this flow is chiefly promoted; so that the amount poured forth will in a great degree depend upon the duration of these movements,—this, again, being governed by the degree in which the food requires mechanical reduction. It seems probable that the average in Man is between 15 and 20 ounces daily.

439. There can be little doubt that the most important action of the Saliva upon the food, is in preparing it for the chemical operations to which it is to be afterwards subjected, by promoting its mechanical reduction in the act of mastication, and by facilitating the subsequent

* "Rapport lu dans la séance de l'Institut," Oct. 25, 1845.

† "Archives Générales de Médecine," 4ième série, tom. xiii.

‡ This idea of M. Bernard's was confirmed by the following experiments. He made an opening into the œsophagus of a Horse, from which he drew the alimentary bolus as it descended; and on weighing it, he found that by the imbibition of saliva it had increased *eleven fold*. He next tied Wharton's duct, and found that the animal required 41 minutes to masticate what had previously required only 9 minutes; and the mass, when withdrawn from the œsophagus, was covered with mucus and a glutinous fluid, the interior being dry and friable, and the whole increased in weight only *three and a half* times.

admixture of other watery fluids, through the intimacy with which it is incorporated with the alimentary matter. Its peculiar physical qualities give it a remarkable adaptation for this purpose; for water could not be so easily or completely incorporated. But there can be no doubt that the peculiar organic constituent of the saliva has a chemical action upon the farinaceous elements of food; for it has been experimentally proved to have the power of converting starch or dextrin into grape-sugar. This power is not peculiar, however, to the Saliva; for M. Bernard has shown that many azotized substances, in a state of incipient decomposition, exert a similar agency; still it appears to be possessed by ptyalin in a much greater degree than by any of these. But as the transformation, at the usual temperature of the body, is not effected with great rapidity, no very great amount of sugar can be thus generated, previously to the entrance of the food into the stomach. There, however, the transforming process may continue; for although it has been usually stated that an alkaline condition of the fluid is necessary for the operation of this 'ferment,' yet it has been shown by Frerichs, and confirmed by Dr. Bence Jones,* that this action continues in the stomach, notwithstanding the acid condition which the Salivary fluid then acquires from admixture with the gastric fluid.—No satisfactory evidence has yet been obtained, that the Saliva has any chemical action upon azotized substances; and, consequently, as regards these constituents of the food, its operation must be considered as purely physical. We shall find that a different secretion is provided for *their* transformation, which has no action upon farinaceous matter.†

440. On its entrance into the Stomach, the food is subjected to the operation of the *Gastric Juice*, which is secreted by the follicles in its walls, or by a certain part of them. This follicular apparatus is extremely extensive, and makes-up the chief part of the thickness of the gastric mucous membrane. If this be divided by a section perpendicular to the surface, it is seen to be almost entirely composed of a multitude of parallel tubuli closely applied to each other, their cæcal extremities abutting against the submucous tissue, and their open ends being directed towards the cavity of the stomach. The conformation of these tubuli is not the same, however, in every part; for whilst they are usually straight and simple, especially in the cardiac portion of the stomach, they are longer and more complicated in the neighbourhood of the pylorus, their deeper parts presenting a sacculated or somewhat convoluted appearance (Fig. 92). Between the tubuli, blood-vessels pass up from the submucous tissue, and form a vascular network on its surface, in the interspaces of which the orifices of the tubes are seen (Fig. 94). From the examination

* "Medical Times," May 31 and June 14, 1851.

† An excellent summary of the present state of our knowledge of the characters and offices of the Saliva, is given by Dr. Bence Jones in the "Medical Times" for May 31, 1851. A summary of M. Bernard's researches on this subject will be found in the "Amer. Journ. of Med. Sci.," Oct. 1851. The Second Volume of Prof. Lehmann's Physiological Chemistry also contains a large amount of information on this subject. Among the most important special contributions to the chemical and physiological history of the Saliva, not previously referred to, are those of Leuchs, by whom the discovery of its power of transforming starch into sugar was first made ("Kastner's Archiv.," 1831, quoted in Müller's "Elements of Physiology," p. 577), Mialhe ("Mémoire sur la digestion et l'assimilation des matières amyloides et sucrées, 1846)," Jacubowitcsh ("De Salivâ," diss. inaug. Dorpati Livon., 1848), and Tilanus (De Salivâ et Muco," diss. inaug., Amstelod., 1849).

of horizontal sections of the Mucous membrane at different depths, Dr. Todd has ascertained that the tubuli are arranged in bundles or groups, surrounded and bound-together by areolar tissue; the size of the bundles, however, and the number of tubules contained in them, vary considerably. The character of the internal surface of the stomach, and the mode in which the tubuli open upon it, are by no means the same in different parts of the organ. When a well-injected preparation is examined with the microscope, it is seen that on the convex surfaces of the rugæ the orifices of the follicles lie singly in the interspaces of the capillary network (Fig. 94, A). But a large proportion of the surface exhibits a sort of honeycombed appearance, being divided by partition-like elevations into pits which are more or less circular or hexagonal in form, their usual diameter being from 100th to 1-250th of an inch, and their depth variable; in the bottom of each of these pits, from three to five (and sometimes more) orifices of the gastric follicles may be seen (Fig. 93). The ridges which divide these pits or alveoli are highly vascular; and the orifices of the follicles lie, as before, in the interspaces of a capillary network which covers the floor of each depression. As we pass towards the pyloric portion of the stomach, however, the ridges which divide the alveoli become more and more elevated, and present conical elongations at certain points; and these elongations become more and more marked, until, in the neighbourhood of the pyloric orifice, they assume the form and appearance of the *villi* of the small intestine (Fig. 94, B), being, however, of much smaller size, and destitute of the lacteal absorbents which give to the latter their distinctive character.*—Of the contents of the gastric follicles, an account has been already given (§ 235); from which it is obvious that here, as elsewhere, the peculiar product which it is their province to elaborate and discharge, is prepared by the agency of the cells which are successively generated in their interior.

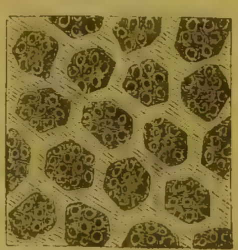
FIG. 92.

A

B

Section of the Mucous Membrane of the Stomach, near the pylorus, showing the *Gastric Follicles*:—A, magnified 3 times; B, magnified 20 times.

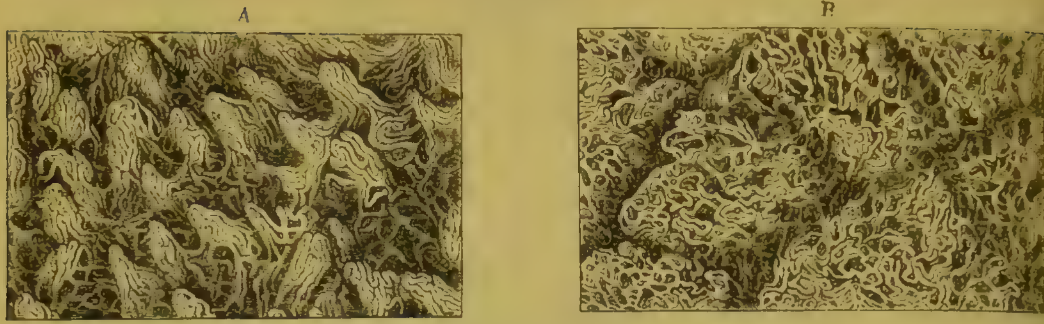
FIG. 93.



Portion of the Mucous Membrane of the Stomach, showing entrances to the gastric follicles, in pits upon its surface.

* See Dr. Sprott Boyd's 'Inaugural Dissertation on the Mucous Membrane of the Stomach,' in the "Edinb. Med. and Surg. Journ.," vol. xlvi.; Dr. Todd's 'Gulstonian Lectures on the Physiology of the Stomach,' in the "Medical Gazette," 1839; and a Memoir by Dr. Neill on the 'Structure of the Mucous Membrane of the Human Stomach,' in the "Amer. Journ. of Med. Sci.," Jan. 1851.—Dr. Neill's object has been to bring prominently into view the *villous* structure of the pyloric portion of the stomach, and the arrangement of the capillaries in other parts. In his exclusive attention to these, however, he has under-estimated the import of the orifices of the gastric follicles, which he speaks of as "simply the subdivisions of the cells into smaller and deeper ones by the arrangement of the blood-vessels." There cannot be the slightest doubt that this arrangement of the blood-vessels is altogether subordinate to the existence and functional activity of the gastric follicles.

FIG. 94.




Appearance of the lining membrane of the *Stomach*, in an injected preparation :—A, from the convex surface of the rugæ ;—B, from the neighbourhood of the pylorus, where the orifices of the gastric follicles occupy the interspaces of the deepest portions of the vascular network.

441. The nature and composition of the *Gastric Juice* which is secreted and poured forth by this follicular apparatus, have been the subjects of much discussion among Chemists; and though certain points may be considered as satisfactorily determined; there are others which still remain doubtful.—This liquid, when obtained without admixture with saliva, is clear, transparent, colourless or slightly yellow, and has very little viscidity. Its specific gravity is not much above that of water; and according to the analysis of Frerichs, it does not contain above 1·72 per cent of solid matter, of which more than half seems to consist of the peculiar 'ferment' to be presently described, the remainder being composed of the chlorides and phosphates of potass, soda, lime, and magnesia. Microscopic examination indicates the persistence of a few of the cells exuviated from the interior of the gastric follicles; but these for the most part leave no other traces than their nuclei and a fine molecular matter arising from their disintegration. The most characteristic feature of the gastric fluid, is its decided acidity, which is very perceptible to the taste. With regard to the nature of the acid, however, there has been much discrepancy of opinion amongst Chemists; for, simple as the problem of its determination might seem, yet it is complicated by the very peculiar property which lactic acid possesses of decomposing the alkaline chlorides at a certain elevation of temperature, the degree being partly determined by the strength of the solution. Hence, supposing lactic acid to be present in the stomach with chloride of sodium, the fluid which passes over by distillation will at first be destitute of hydrochloric acid; but, as the liquor becomes more concentrated, and the temperature rises, hydrochloric acid will appear. This, it has been alleged by Bernard, R. D. Thomson, Lehmann, and other Chemists, is the true source of the hydrochloric acid which may be always obtained from the gastric juice by this process; and it is affirmed by them that Lactic acid is the real agent in the solvent process to which that fluid is subservient, the presence of free lactic acid in the stomach having been determined by other means. But however true this conclusion may be in regard to dogs and pigs, which are the animals that have been chiefly experimented-on for this purpose, there appears to be valid evidence that it is not applicable to Man. In the first place, the great readiness with which hydrochloric acid was obtained by Prof. Dunglison from the pure gastric fluid drawn from the stomach of Alexis St. Martin, and the fact that the smell of hydrochloric

acid might be distinctly recognized in the fresh juice,* are strong evidences in favour of the belief that (as originally maintained by Dr. Prout) free hydrochloric acid is present in this fluid, and that it is the principal if not the only source of its acidity. And an opportunity having been recently afforded to Dr. Bence Jones of obtaining pure gastric fluid, and this having been placed in the hands of Prof. Graham for examination, this distinguished Chemist has succeeded in separating hydrochloric acid from it by his method of 'liquid diffusion,' which is not open to the objection that applies to distillation; and although he has found free lactic acid to be also present, its quantity is comparatively small.† The truth appears to be, that both the hydrochloric and lactic acids may give to the gastric fluid the peculiar solvent power, which (as will be presently shown) it possesses for albuminous substances, and that one may take the place of the other; so that whilst in Man, hydrochloric acid is the chief source of the acidity, lactic acid may be so in the dog and pig. Acetic, butyric, and phosphoric acids have also been occasionally met with in the gastric fluid; but they can scarcely be reckoned among its normal constituents.

442. The peculiar organic 'ferment' of the gastric juice, to which the name of *Pepsin* has been given, was first obtained in an isolated state by Wasmann; who has given the following account of the properties and reactions of that which he procured from the mucous membrane of the stomach of the Pig, which greatly resembles that of Man. When this membrane is digested in a large quantity of water at from 85° to 95°, many other matters are removed from it besides pepsin; but if this water be poured-off, and the digestion be continued with fresh water in the cold, very little but pepsin is then taken up. Pepsin appears to be but sparingly soluble in water; when its solution is evaporated to dryness, there remains a brown, greyish, viscid mass, with the odour of glue, and having the appearance of an extract. The solution of this in water is turbid, and still possesses a portion of the characteristic power of pepsin, but greatly reduced. When strong alcohol is added to a fresh solution of pepsin, the latter is precipitated in white flocks, which may be collected on a filter, and produce a grey compact mass when dried. Pepsin enters into chemical combination with many acids, forming compounds which still redden litmus paper; and it is when thus united with acetic and muriatic acids, that its solvent powers are the greatest.‡—The general result of later inquiries has been to confirm the views laid down in the following statement of Wasmann's inquiries. "In regard to the solvent power of pepsin for coagulated albumen, it was observed by M. Wasmann that a

* See Prof. Dunglison's "Human Physiology," 7th edit., vol. i. pp. 585–6.

† For his knowledge of this fact, the Author is indebted to Prof. Graham.—That Hydrochloric acid is the source of the acidity of the gastric juice has also been maintained by Enderlin ("Canstatt's Jahresbericht," 1843, p. 149), and recently by Hübbenet ("Disquisitiones de Succo Gastrico," diss. inaug., Dorpat, 1850).

‡ It has been supposed by Prof. Schmidt (of Dorpat), that the union of pepsin with these and other acids forms a 'conjugated' acid (§ 58, *note*), which possesses the property of forming soluble compounds with albuminous and other azotized substances; but the existence of such an acid has not been determined by the analysis of any combination either with a mineral base or with an albuminous substance; and the numerous experiments which have been made by Prof. Lehmann regarding the digestive agents and substances to be digested, indicate no such definite proportion between them, as this view of the constitution of the former would require.

liquid which contains 17-10,000ths of acetate of pepsin, and 6 drops of hydrochloric acid per ounce, possesses a very sensible solvent power, so that it will dissolve a thin slice of coagulated albumen in the course of 6 or 8 hours' digestion. With 12 drops of hydrochloric acid per ounce, the white of egg is dissolved in 2 hours. A liquid which contains $\frac{1}{2}$ gr. of acetate of pepsin, and to which hydrochloric acid and white of egg are alternately added, so long as the latter dissolves, is capable of taking up 210 grains of coagulated white of egg at a temperature between 95° and 104°. It would appear, from such experiments, that the hydrochloric acid is the true solvent, and that the action of the pepsin is limited to that of *disposing* the white of egg to dissolve in hydrochloric acid. The acid when alone dissolves white of egg by ebullition, just as it does under the influence of pepsin; from which it follows that pepsin replaces the effect of a high temperature, which is not possible in the stomach. The same acid with pepsin dissolved blood, fibrin, meat and cheese; while the isolated acid dissolved only an insignificant quantity at the same temperature; but when raised to the boiling point, it dissolved nearly as much, and the part dissolved appeared to be of the same nature. The epidermis, horn, the elastic tissue (such as the fibrous membrane of arteries) do not dissolve in a dilute acid containing pepsin. M. Wasmann has remarked that the pepsin of the stomach of the pig is entirely destitute of the power to coagulate milk, although the pepsin of the stomach of the calf possesses it in a very high degree; from which he is led to suppose, that the power of the latter depends upon a particular modification of pepsin, or perhaps upon another substance accompanying it, which ceases to be formed when the young animal is no longer nourished by the milk of its mother." *

443. It is only when either alimentary or some other substances capable of exciting irritation are present in the Stomach, that this acid secretion is poured forth. So long as it is empty, the secretion which moistens its walls is neutral or even alkaline; but as soon as food is taken, acid is poured forth, and this in increasing quantities, until a certain time after the commencement of the digestive process, when the acidity of the stomach is at its maximum. In proportion as the alimentary matter is dissolved, however, and is either at once absorbed, or escapes through the pyloric orifice, the acidity of the stomach diminishes; and as soon as its cavity is emptied, the secretion of its walls is neutral again.†—A very important series of observations on the conditions under which the Gastric juice is secreted, was made some years since by Dr. Beaumont, in the remarkable case of Alexis St. Martin, already several times referred to.‡ "The inner coat of the stomach (as seen through the fistulous orifice) in its natural and healthy state, is of a light or pale pink colour, varying in its hues, according to its full or empty state. It is of a soft or velvet-like appearance, and is constantly covered with a very thin, transparent, viscid mucus, lining the whole interior of the organ. By applying aliment or other irritants, to the internal coat of the stomach, and observing the effect through a magnify-

* Prof. Graham's "Elements of Chemistry," pp. 1031–1033.

† See Dr. Bence Jones, in "Medical Times," June 14, 1852.

‡ See Dr. Beaumont's "Experiments and Observations on the Gastric Juice and the Physiology of Digestion," reprinted with notes by Dr. Andrew Combe, Edinb., 1838.

ing glass, innumerable lucid points, and very fine [nervous or vascular] papillæ can be seen arising from the villous membrane, and protruding through the mucous coat, from which distils a pure, limpid, colourless, slightly viscid fluid." (The papillæ here described appear to be the orifices of the gastric follicles, which are usually closed by their epithelial cells during fasting, and which would seem to become prominent when the *vis a tergo* of the secreted fluid first causes this plug of cells to be cast forth.) "The fluid thus excited is invariably distinctly acid. The mucus of the stomach is less fluid, more viscid or albuminous, semi-opaque, sometimes a little saltish, and does not possess the slightest character of acidity. The gastric fluid never appears to be accumulated in the cavity of the stomach while fasting; and is seldom, if ever, discharged from its proper secerning vessels, except when excited by the natural stimulus of aliment, mechanical irritation of tubes, or other excitants. When aliment is received, the juice is given out in exact proportion to its requirements for solution, except when more food has been taken than is necessary for the wants of the system."—The observations of Dr. Beaumont have been confirmed by those of M. Blondlot* and of M. Cl. Bernard,† which were made upon Dogs, in whose stomachs fistulous openings were maintained for a length of time. They found that the flow of gastric fluid is more excited by pepper, salt, and soluble stimulants, than it is by mechanical irritation; and that if mechanical irritation be carried beyond certain limits, so as to produce pain, the secretion, instead of being more abundant, diminishes or ceases entirely; whilst a ropy mucus is poured out instead, and the movements of the stomach are considerably increased. The animal at the same time appears ill at ease, is agitated, has nausea, and, if the irritation be continued, actual vomiting; and bile has been observed to flow into the stomach, and escape by the fistulous opening. Similar disorders of the functions of the stomach result from violent pain in other parts of the body; the process of digestion in such cases being suspended, and sometimes vomiting excited. When acidulated substances, as food rendered acid by the addition of a little vinegar, were introduced into the stomach, the quantity of gastric fluid poured out was much smaller, and the digestive process consequently slower, than when similar food, rendered alkaline by a weak solution of carbonate of soda, was introduced. If, however, instead of a weak solution, carbonate of soda in crystal or in powder was introduced into the stomach, a large quantity of mucus and bile, instead of gastric fluid, flowed into the stomach; and vomiting and purging very often followed. When very cold water, or small pieces of ice, were introduced into the stomach, the mucous membrane was at first rendered very pallid; but soon a kind of reaction followed, the membrane became turgid with blood, and a large quantity of gastric fluid was secreted. If, however, too much ice was employed, the animal appeared ill, and shivered; and digestion, instead of being rendered more active, was retarded. Moderate heat, applied to the mucous surface of the stomach, appeared to have no particular action on digestion; but a high degree of heat produced most serious consequences. Thus, the introduction of a little boiling water threw the animal at once into a kind of adynamic state, which was followed by death in three or four hours; the mucous membrane of

* "Traité Analytique de la Digestion."

† "Archiv. d'Anat. Gén. et de Physiol.," Jan. 1846.

the stomach was found red and swollen, whilst an abundant exudation of blackish blood had taken place into the cavity of the organ. Similar injurious effects resulted in a greater or less degree, from the introduction of other irritants, such as nitrate of silver or ammonia; the digestive functions being at once abolished, and the mucous surface of the organ rendered highly sensitive.

444. That the quantity of the Gastric Juice secreted from the walls of the stomach depends rather upon the general requirements of the system, than upon the quantity of food introduced into the digestive cavity, is a principle of the highest practical importance, and cannot be too steadily kept in view in Dietetics. A *definite proportion* only of aliment can be perfectly digested in a given quantity of the fluid; the action of which, like that of other chemical operations, ceases after having been exercised on a fixed and definite amount of matter. "When the juice has become saturated, it refuses to dissolve more; and, if an excess of food has been taken, the residue remains in the stomach, or passes into the bowels in a crude state, and becomes a source of nervous irritation, pain, and disease, for a long time." The unfavourable effect of an undue burthen of food upon the Stomach itself, interferes with its healthy action: and thus the quantity really appropriate is not dissolved. The febrile disturbance is thus increased; and the mucous membrane of the stomach exhibits evident indications of its morbid condition. The description of these indications given by Dr. Beaumont, is peculiarly graphic, as well as Hygienically important. "In disease, or partial derangement of the healthy function, the mucous membrane presents various and essentially-different appearances. In febrile conditions of the system, occasioned by whatever cause,—obstructed perspiration, undue excitement by stimulating liquors, overloading the stomach with food, fear, anger, or whatever depresses or disturbs the nervous system,—the villous coat becomes sometimes red and dry, at other times pale and moist, and loses its smooth and healthy appearance; the secretions become vitiated, greatly diminished, or even suppressed; the coat of mucus scarcely perceptible, the follicles flat and flaccid, with secretions insufficient to prevent the papillæ from irritation. There are sometimes found, on the internal coat of the stomach, eruptions of deep-red pimples, not numerous, but distributed here and there upon the villous membrane, rising above the surface of the mucous coat. These are at first sharp-pointed, and red, but frequently become filled with white purulent matter. At other times, irregular, circumscribed red patches, varying in size and extent from half an inch to an inch and a half in circumference, are found on the internal coat. These appear to be the effects of congestion in the minute blood-vessels of the stomach. There are also seen at times small aphthous crusts, in connection with these red patches. Abrasion of the lining membrane, like the rolling-up of the mucous coat into small shreds or strings, leaving the papillæ bare for an indefinite space, is not an uncommon appearance. These diseased appearances, when very slight, do not always affect essentially the gastric apparatus. When considerable, and particularly when there are corresponding symptoms of disease,—as dryness of the mouth, thirst, accelerated pulse, &c.—*no gastric juice can be extracted by the alimentary stimulus.* Drinks are immediately absorbed or otherwise disposed of; but food taken in this condition of the stomach remains undigested for

twenty-four or forty-eight hours, or more, increasing the derangement of the alimentary canal, and aggravating the general symptoms of disease. After excessive eating or drinking, chymification is retarded; and, though the appetite be not always impaired at first, the fluids become acrid and sharp, excoriating the edges of the aperture, and almost invariably producing aphthous patches and the other indications of a diseased state of the internal membrane. Vitiated bile is also found in the stomach under these circumstances, and flocculi of mucus are more abundant than in health. Whenever this morbid condition of the stomach occurs, with the usual accompanying symptoms of disease, there is generally a corresponding appearance of the tongue. When a healthy state of the stomach is restored, the tongue invariably becomes clean." *

445. That the secretion of Gastric Juice is affected in a very marked manner by conditions of the Nervous system, is indicated by the effect of mental emotions in putting an immediate stop to the digestive process, when it is going on with full vigour. But it is still more conclusively proved by the effect of division of the Pneumogastric nerve; which almost instantaneously checks the elaboration of the fluid. The most satisfactory evidence of the influence of this operation is afforded by the experiments of M. Bernard upon dogs in whose stomachs fistulous orifices had been established. For when the section was made during the free flow of gastric juice (through a canula previously introduced into the stomach), excited by the presence of an alimentary bolus, the flow immediately ceased, and the mucous membrane, which had been tense and turgid the moment before, became withered and pale. On introducing the finger into the stomach itself, the walls were perceived to be perfectly flaccid, and there was no longer the gentle pressure which had been previously felt. The rapidity and completeness of this influence are further demonstrated by the following ingenious experiment, devised by M. Bernard. The two substances *emulsin* (the albuminous matter found in almonds) and *amygladin* (the active principle of bitter almonds) are quite innocuous when administered separately; but when they are united, a production of hydrocyanic acid takes place; so that, if this should occur in the stomach of an animal, the poison proves fatal, provided that it be generated in sufficient quantity. If, however, the emulsin be given first, and the amygdalin half an hour afterwards, no such result occurs; because the properties of the emulsin are so changed

* Dr. A. Combe's commentary on the above passage is too apposite to be omitted. "Many persons who obviously live too freely, protest against the fact, because they feel no immediate inconvenience, either from the quantity of food, or the stimulants in which they habitually indulge; or, in other words, because they experience no pain, sickness, or headache,—nothing, perhaps, except slight fulness and oppression, which soon go off. Observation extended over a sufficient length of time, however, shows that the conclusion drawn is entirely fallacious, and that the real amount of injury is not felt at the moment, merely because, for a wise purpose, nature has deprived us of any consciousness of either the existence or the state of the stomach during health. In accordance with this, Dr. Beaumont's experiments prove, that extensive erythematic inflammation of the mucous coat of the stomach was of frequent occurrence in St. Martin after excesses in eating, and especially in drinking, even when no marked general symptom was present to indicate its existence. Occasionally, febrile heat, nausea, headache, and thirst were complained of, but not always. Had St. Martin's stomach, and its inflamed patches, not been visible to the eye, he too might have pleaded that his temporary excesses did him no harm; but, when they presented themselves in such legible characters that Dr. Beaumont could not miss seeing them, argument and supposition were at an end, and the broad fact could not be denied."

by the gastric fluid secreted during the interval, that it no longer generates hydrocyanic acid with amygdalin. But if the emulsin be given to an animal whose pneumogastric nerves have been just divided, and the amygdalin be administered half an hour subsequently, the effect is the same as if the two substances had been given at one time; showing that no secretion of gastric fluid could have taken place.—The first obvious effects of this operation are vomiting (in animals that are capable of it) and loathing of food; and the arrestment of the digestive process is indicated, on post-mortem examination some hours afterwards, by the absence of any digestive change in food that may have been taken just previously to the operation, and that has not been ejected from the stomach.

446. But, as was first proved by Dr. John Reid,* a re-establishment of the digestive power manifests itself after an interval of some days, if the animals should survive so long. In the animals which died within the first four or five days, no indication of this restoration could be discovered by Dr. R.; in those which survived longer, great emaciation took place; but when life was sufficiently prolonged, the power of assimilation seemed almost completely restored. This was the case in four out of the seventeen dogs experimented on; and the evidence of this restoration consisted in the recovery of flesh and blood by the animals, the vomiting of half-digested food permanently reddening litmus paper, the disappearance of a considerable quantity of alimentary matter from the intestinal canal, and the existence of chyle in the lacteals. It may serve to account in some degree for the contrary results obtained by other experimenters, to state that seven out of Dr. R.'s seventeen experiments were performed before he obtained any evidence of digestion after the operation, and that the four which furnished this followed one another almost in succession; so that it is easy to understand why those, who were satisfied with a small number of experiments, should have been led to deny it altogether.—Another series of experiments was performed by Dr. Reid, for the purpose of testing the validity of the results obtained by Sir B. Brodie, relative to the effects of section of the Par Vagum upon the secretions of the stomach, after the introduction of arsenious acid into the system. According to that eminent Surgeon and Physiologist,† when the poison was introduced after the Pneumogastric had been divided on each side, the quantity of the protective mucous and watery secretions was much less than usual, although obvious marks of inflammation were present. In order to avoid error as much as possible, Dr. Reid made five sets of experiments, employing two dogs in each, as nearly as possible of equal size and strength, introducing the same quantity of the poison into the system of each in the same manner, but cutting the Vagi in one, and leaving them entire in the other. This *comparative* mode of experimenting is obviously the only one admissible in such an investigation. Its result was in every instance opposed to the statements of Sir B. Brodie; the quantity of the mucous and watery secretions of the stomach being nearly the same in each individual of the respective pairs subjected to expe-

* "Edinb. Med. and Surg. Journ.," April, 1839; and "Physiological, Anatomical, and Pathological Researches," CHAP. V.—Dr. Reid's results have been confirmed as to this important particular by Hübbenet (Op. cit.)

† "Philosophical Transactions," 1814, p. 102.

riment; so that their production can no longer be referred to the influence of the Pneumogastric nerves. Moreover, the appearances of inflammation were, in four out of the five cases, greatest in the animals whose Vagi were left entire; and this seemed to be referable to the longer duration of their lives after the arsenic had been introduced. The results of Sir B. Brodie's experiments may perhaps be explained, by the speedy occurrence of death in the subjects of them, consequent (it may be) upon the want of sufficiently free respiration, which was carefully guarded-against by Dr. Reid.

447. It must be held as demonstrated by these experiments, then, that all the arguments which have been drawn from the effects of lesion of the Pneumogastrics upon the functions of the Stomach, in favour of the doctrine that Secretion *depends upon* Nervous agency, must be set aside. That these nerves have an important *influence* on the gastric secretion, is evident from the deficiency in its amount soon after their section, as well as from other facts. But this is a very different proposition from that just alluded to; and the difference has been very happily illustrated by Dr. Reid. "The movements of a horse," he observes, "are independent of the rider on his back,—in other words, the rider does not furnish the conditions necessary for the movements of the horse;—but every one knows how much these movements may be influenced by the hand and heel of the rider." It may be hoped, then, that physiologists will cease to adduce the oft-cited experiments of Dr. Wilson Philip, in favour of the hypothesis (for such it must be termed) that secretion is dependent upon nervous influence, and that this is identical with galvanism. Additional evidence of their fallacy is derived from the fact mentioned by Dr. Reid, that the usual *mucous* secretions of the stomach were always found; and they are further invalidated by the testimony of Müller, who denies that galvanism has any peculiar influence in re-establishing the gastric secretion, when it has been checked by section of the nerves.

448. Our knowledge of the nature of the process of *Gastric Digestion* has been greatly advanced by recent inquiries; and we are now in a condition to state with considerable precision what it is, and what it is not, the province of the gastric juice to effect.—There can no longer be any doubt that the operation is one essentially of *chemical solution;* and that the *vital* attributes of the Stomach are only exercised in the preparation of the solvent, and in the performance of those movements which promote its action on the alimentary matters submitted to it. The first series of facts which clearly demonstrated this position, were those that resulted from the very pains-taking observations made by Dr. Beaumont, in the case of St. Martin already referred to. By introducing a tube of India-rubber into the empty stomach, Dr. B. was able to obtain a supply of gastric juice whenever he desired it, the tube serving the purpose of stimulating the follicles to pour forth their secretion, and at the same time conveying it away; and with the fluid thus obtained, he was able to make various experiments, which showed that the change which it effects upon alimentary matter, when it is kept at a temperature of 98° or 100°, and frequently agitated, is not less complete than that which takes place when the same matter is submitted to its operation within the stomach, but requires a longer time. This is readily accounted-for when we remember, that no ordinary agitation can produce the same effect with the curious movements of the stomach; and that the continual removal, from

its cavity, of the matter which has been already dissolved, must aid the operation of the solvent on the remainder. The following is one out of many experiments detailed by Dr. Beaumont. "At $11\frac{1}{2}$ o'clock, A.M., after having kept the lad fasting for 17 hours, I introduced a gum-elastic tube, and drew off one ounce of pure gastric liquor, unmixed with any other matter, except a small proportion of mucus, into a three-ounce vial. I then took a solid piece of boiled recently-salted beef, weighing three drachms, and put it into the liquor in the vial; corked the vial tight, and placed it in a saucepan filled with water, raised to the temperature of 100°, and kept at that point on a nicely-regulated sand-bath. In *forty* minutes, digestion had distinctly commenced over the surface of the meat. In *fifty* minutes, the fluid had become quite opaque and cloudy; the external texture began to separate and become loose. In *sixty* minutes, chyme began to form. At 1 o'clock, P.M. (digestion having progressed with the same regularity as in the last half-hour), the cellular texture seemed to be entirely destroyed, leaving the muscular fibres loose and unconnected, floating about in fine small shreds, very tender and soft. At 3 o'clock, the muscular fibres had diminished one-half, since the last examination. At 5 o'clock, they were nearly all digested; a few fibres only remaining. At 7 o'clock, the muscular texture was completely broken down, and only a few of the small fibres could be seen floating in the fluid. At 9 o'clock every part of the meat was completely digested. The gastric juice, when taken from the stomach, was as clear and transparent as water. The mixture in the vial was now about the colour of whey. After standing at rest a few minutes, a fine sediment of the colour of the meat, subsided to the bottom of the vial.—A piece of beef, exactly similar to that placed in the vial, was introduced into the stomach, through the aperture, at the same time. At 12 o'clock it was withdrawn, and found to be as little affected by digestion as that in the vial; there was little or no difference in their appearance. It was returned to the stomach; and, on the string being drawn out at 1 o'clock, P.M., the meat was found to be all completely digested and gone. The effect of the gastric juice on the piece of meat suspended in the stomach, was exactly similar to that in the vial, only more rapid after the first half-hour, and sooner completed. Digestion commenced on, and was confined to, the surface entirely in both situations. Agitation accelerated the solution in the vial, by removing the coat that was digested on the surface, enveloping the remainder of the meat in the gastric fluid, and giving this fluid access to the undigested portions."* Many variations were made in other experiments; some of which strikingly displayed the effects of thorough mastication, in aiding both natural and artificial digestion.

449. The attempt was made by Dr. Beaumont, to determine the relative digestibility of different articles of diet, by observing the length of time requisite for their solution.† But, as he himself points out, the rapidity of digestion varies so greatly, according to the quantity eaten, the

* Experiments 2 and 3 of First Series.

† It is important to bear in mind that the digestibility of different substances bears no relation to their nutrient value, which is entirely dependent on their chemical composition. Of course, however nutritious a substance may be, it is valueless as an article of diet if it cannot be dissolved; but, on the other hand, substances which are very easily digested (such as farinaceous matters) may have a low nutritive value, through containing but a very small proportion of azotized constituents.

nature and amount of the previous exercise, the interval since the preceding meal, the state of health, the condition of the mind, and the nature of the weather, that a much more extended inquiry would be necessary to arrive at results to be depended on. Some important inferences of a general character, however, may be drawn from his inquiries.—It seems to be a general rule, that the flesh of wild animals is more easy of digestion, than that of the domesticated races which approach them most nearly. This may, perhaps, be partly attributed to the small quantity of fatty matter that is mixed up with the flesh of the former, whilst that of the latter is largely pervaded by it. For it appears from Dr. B.'s experiments, that the presence in the stomach of any substance which is difficult of digestion, interferes with the solution of food that would otherwise be soon reduced. It seems that, on the whole, Beef is more speedily reduced than Mutton, and Mutton sooner than either Veal or Pork. Fowls are far from possessing the digestibility that is ordinarily imputed to them; but Turkey is, of all kinds of flesh except Venison, the most soluble.—Dr. Beaumont's experiments further show, that *bulk* is as necessary for healthy digestion, as the presence of the nutrient principle itself. This fact has been long known by experience to uncivilised nations. The Kamschatdales, for example, are in the habit of mixing earth or saw-dust with the train-oil, on which alone they are frequently reduced to live. The Veddahs or wild hunters of Ceylon, on the same principle, mingle the pounded fibres of soft and decayed wood with the honey, on which they feed when meat is not to be had; and on one of them being asked the reason of the practice, he replied, "I cannot tell you, but I know that the belly must be filled." It is further shown by Dr. B., that soups and fluid diet are not more readily chymified than solid aliment, and are not alone fit for the support of the system; and this, also, is conformable to the well-known results of experience; for a dyspeptic patient will frequently reject chicken-broth, when he can retain solid food or a richer soup. Perhaps, as Dr. A. Combe remarks, the little support gained from fluid diet, is due to the rapid absorption of the watery part of it; so that the really nutritious portion is left in too soft and concentrated a state, to excite the healthy action of the stomach.—Dr. Beaumont also ascertained, that moderate exercise facilitates digestion, though severe and fatiguing exercise retards it. If even moderate exercise be taken *immediately* after a *full* meal, however, it is probably rather injurious than beneficial; but if an hour be permitted to elapse, or if the quantity of food taken have been small, it is of decided benefit. The influence of temperature on the process of solution, is remarkably shown in some of Dr. B.'s experiments. He found that the gastric juice had scarcely any influence on the food submitted to it, when the bottle was exposed to the cold air, instead of being kept at a temperature of 100°. He observed on one occasion, that the injection of a single gill of water at 50° into the stomach, sufficed to lower its temperature upwards of 30°; and that its natural heat was not restored for more than half an hour. Hence the practice of eating ice after dinner, or even of drinking largely of cold fluids, is very prejudicial to digestion.

450. It is far from being true, however, that, according to the older views of the power of the Gastric juice, it is capable of acting upon *all* the nutritive components of the food. The mistake probably arose from

the *reduction* to which these matters are subjected in digestion, the alimentary bolus being completely disintegrated, and its particles saturated with the fluids of the stomach, so that the whole forms a homogeneous liquid of pultaceous consistence, to which the name of *chyme* is given. This chyme will, of course, vary greatly in its composition, according to the proportion of the different alimentary substances that have entered into the composition of the food; and its appearance, also, is far from uniform, being sometimes like gruel, but sometimes more creamy, always, however, having a strong acid reaction.—All the more recent and accurate experiments of those who have studied the chemistry of digestion, leads to the conclusion, that the solvent powers of the Gastric Juice are entirely limited to *azotized* substances; and that it exerts no action whatever either upon starchy, saccharine, or oleaginous matters. Although the change in the starchy particles, which commenced in the mouth, is usually continued in the stomach, yet its continuance is entirely dependent upon the presence of the salivary fluid; being completely checked, when, by tying the œsophagus, that fluid is prevented from passing into the stomach*. Saccharine matters, being readily soluble in water, do not require the agency of the gastric fluid, for any other purpose than the solution of their investments, whereby they are set free; and it does not appear that it exerts any converting power upon them. So, again, Oleaginous matters are merely reduced to a state of fine division, and are diffused in a state of suspension through the pulpy chyme. The effect of the gastric fluid upon the several kinds of Albuminous matters, is to reduce them to a state of complete solution, and at the same time to alter their chemical properties, so that they for the most part lose their distinctive attributes, and are brought to one uniform condition, that of *albuminose* (§ 167), which seems to be the state best adapted for subsequent assimilation. In this condition they seem to form definite combinations with the solvent fluid, which have received the name of *peptones.* That these combinations, however, are very different from mere solutions of the same matters in acidulated liquids, has been shown by the experiments of M. Bernard; who found that, on injecting the solution of albumen in very dilute hydrochloric acid into the general circulation, the liquid speedily passed off by the renal secretion; whilst after injecting the solution of albumen in gastric juice, no trace of this could be detected in the urine. Hence it seems evident that the *converting* power is exerted by the pepsin, or peculiar 'ferment' of the gastric fluid, whilst the *solvent* power is due to the acid; a conclusion which agrees well with that based on other evidence (§ 442). It appears from the observations of MM. Blondlot and Bernard, that when liquid Albumen is taken into the stomach, it does not undergo complete coagulation before the solvent process commences, but merely becomes opalescent; Casein, on the other hand, is completely coagulated, the peculiar animal principle of the gastric fluid having more power of precipitating it than is possessed by any other re-agent (§ 22). It is estimated by Lehmann, that about 20 parts of fresh gastric juice (of the dog) are required to dissolve 1 part of albumen; and as the quantity of albuminous matter daily consumed by Man may be estimated at between 3 and 4 oz., it would hence appear that the amount of gastric fluid secreted must

* See Frerichs in "Wagner's Handwörterbuch," Art. 'Verdauung.'

be from 60 to 80 oz. This mode of calculation seems to afford the only means of forming even an approximative idea of the quantity of fluid poured forth from the walls of the stomach. Of course by far the larger proportion of this must be re-absorbed, either through the vessels of the stomach itself, or through those of the intestinal canal.—The gastric fluid has also a special solvent power for Gelatinous substances; acting upon those which would have otherwise required long boiling for their disintegration. Here too, the marked difference in action between the gastric juice and a merely acidulous fluid, has been demonstrated by M. Bernard; who has shown that, when a piece of bone is submitted to the latter, its mineral portion alone is affected by it; whereas when it is subjected to the former, the gastric juice digests the gelatin, and leaves the phosphates and carbonates unaltered. Here, too, a decided transformation is effected by the operation of the gastric fluid; for the gelatin of the peptone has lost its power of gelatinizing, and is not precipitated by chlorine.

451. This action of the Gastric solvent upon the azotized constituents of the food, is dependent upon several conditions. One of the most important of these is *temperature.* A heat of from 96° to 100° is required to keep up the solvent process, which is retarded according to the depression of the thermometer below this standard; so that at the ordinary temperature of the atmosphere it is completely suspended, to be renewed, however, with an increment of heat. On the other hand, a trifling elevation of temperature above 100° occasions a decomposition in the gastric juice, which entirely destroys its solvent power. The next condition, which specially affects the time required for the process of solution, is *motion.* This does not act mechanically, by way of 'trituration,' as was once supposed; for food is found to be digested, when enclosed in metallic balls perforated to admit the access of gastric juice to their interior. But it answers the purpose of thoroughly subjecting the whole of the alimentary bolus to the agency of the gastric solvent, by bringing each part successively into contact with the lining membrane of the stomach from the surface of which the fluid is effused. The *removal of the matters already reduced or dissolved,* also, has a most important effect in facilitating the solution of the remainder. This removal is due in part to the absorption of the matters in a state of solution, into the blood-vessels of the walls of the stomach (§ 462); and in part to the successive escape of the reduced portions through the pyloric orifice (§ 429). The importance of the previous state of *minute division* and *incorporation with aqueous fluid,* in promoting the action of the gastric solvent, has been already dwelt on (§ 424).

452. Although the *Chyme,* or product of gastric digestion, which escapes through the pyloric orifice into the duodenum, contains much azotized matter in a state of actual *solution,* a considerable proportion of it is still only *reduced* and mechanically *suspended;* and the solution of the latter is continued in the intestinal tube. In the farinaceous part of the food, moreover, no great amount of change has hitherto been effected; and the sugar which has been generated by the agency of the salivary ferment, is probably absorbed into the blood-vessels nearly as fast as it is formed. In the condition of the fatty matters, no important change is perceptible, except such as results from the solution of the membranes, &c., that enclosed them. Hence we see that the process of Digestion, so far from being completed in the stomach, has only been carried one stage

further. Soon after its entrance into the Duodenum, the chyme is subjected to the actions of the bile, the pancreatic fluid, and that secretion from the glandulæ in the walls of the intestine itself (probably proceeding chiefly, however, from the glands of Brunner, § 235), which is known under the name of the 'succus entericus.'—Of these, the *Pancreatic* fluid will be first noticed. The structure of the Pancreas closely resembles that of the Salivary glands (§ 436); for it consists of racemose clusters of secreting follicles, which form the terminations of the ramifying divisions of the duct; each cluster, with its blood-vessels, lymphatics, nerves, and connecting tissue, forming a lobule; and the separate lobules being held together by areolar tissue, as well as by the vessels and ducts. Like the salivary glands, moreover, its development commences by a sort of budding-forth of the alimentary canal at a particular spot, upon which a mass of cells has previously accumulated. The secretion of this gland strongly resembles saliva in its general appearance, being clear and colourless, slightly viscid, and alkaline in its reaction; it contains, however, a larger proportion of solid matter, its specific gravity being 1008 or 1009; and the nature of its animal principle is not precisely the same. The following is Prof. Frerichs' analysis of the pancreatic fluid of the Ass.

| | | |
|---|---|---|
| Water | 986·40 | |
| Solids | 13·60 | |
| Fat | | 0·26 |
| Alcohol-extract | | 0·15 |
| Water-extract, albuminous | | 3·09 |
| Alkaline { Chlorides, Phosphates, Sulphates } | | 8·90 |
| Carbonate and phosphate of lime and magnesia | | 1·20 |
| | 1000·00 | 13·60 |

The albuminous 'ferment' is not perfectly coagulable by heat, and when precipitated by alcohol it redissolves readily in water; it is precipitated by sulphuric, nitric, and concentrated hydrochloric acid, and by the metallic salts; and when thrown down by these, or by heat, it is redissolved by alkalies. It is also precipitated by acetic acid; but it slowly redissolves in an excess of the reagent, and on the application of heat; and from this solution it is precipitated by ferrocyanide of potassium. When boiled with ammonia, it assumes an intense yellow colour. The readiness with which this substance undergoes change, is indicated by the rapidity with which the pancreatic fluid passes into decomposition; for even after a few hours' exposure to the air, it gives off a decidedly putrid odour. Like ptyalin, this peculiar constituent of the pancreatic fluid possesses the power (though in a less degree) of converting starch into sugar; there can be no doubt, therefore, that it is subservient to the continued digestion of the farinaceous part of the food, during its passage through the small intestines. It shares this office, however, with the 'succus entericus,' which has been shown by Frerichs and Hübbenet to be also possessed of this converting power.—It has recently been affirmed by M. Cl. Bernard, and strong evidence has been adduced by him in support of his statement, that the *essential* purpose of the pancreatic fluid is to promote the absorption of fatty matters, by reducing them to the state of an *emul-*

*sion*, which is capable of finding its way into the lacteals.* That this fluid possesses the emulsifying power in a peculiar degree, may be considered as having been fully demonstrated by his experiments; for on mixing it with oil, butter, or any variety of fat, at a temperature sufficiently high to render the fatty substance liquid, and then stirring the mixture for a few minutes, an emulsion is produced bearing a strong resemblance to chyle. This emulsion does not cease to present its peculiar aspect, although left standing for some time; whereas although bile, saliva, gastric juice, blood-serum, and other animal fluids, have a certain emulsifying power, yet after a short time the oil-particles run together again, almost as if they had been merely shaken-up with water. Further, it is asserted by Bernard, that in the Rabbit (in which the pancreatic duct discharges itself some inches lower down in the intestine than does the bile-duct), when fatty matters have been introduced into the alimentary canal, they undergo no considerable change, until they have passed the orifice of the pancreatic duct; an oily emulsion being then for the first time found in the intestinal canal; and the contents of those absorbents only having the opaque whiteness of chyle, which originate in the intestinal villi below that orifice. So, again, M. Bernard affirms that by putting a ligature round the pancreatic duct, the digestion of oleaginous matter is so completely prevented, that it is found unchanged in the lower part of the intestinal tube, and no opalescent chyle is found in the lacteals. This position is further strengthened by the fact ascertained by clinical observation,† that there is a close relation between disease of the pancreas, and the discharge of fatty matters per anum (§ 198).—It has been shown, however, by the experimental researches of Frerichs, Lehmann, Lenz,‡ and others, that the statements of M. Bernard are too exclusive in their character; for that the digestion and absorption of fatty matters will take place after the pancreatic duct has been tied (sufficient time having been given for the evacuation of any pancreatic fluid which may have been in the alimentary canal previously to the operation), and even in the lower part of the small intestine, into which these substances have been conveyed by injection, after it has been completely separated by a ligature from the upper part into which the pancreatic fluid has been poured. It further appears from their experiments, that a *mixture* of the pancreatic fluid with bile and the 'succus entericus' possesses a more energetic emulsifying power than the first of these fluids alone; and it seems probable that, as in the conversion of starch, so in the emulsification of fat, the intestinal fluid performs a very important part. It would not seem

* "Archiv. Génér. de Méd.," tom. xix.—It has been assumed by Frerichs, Lenz, and other objectors to M. Bernard's views, that he maintains that the pancreatic fluid *saponifies* the neutral fatty matters taken-in as food, converting them into fatty acids and glycerine whilst yet within the intestinal canal. It is no doubt true that M. Bernard considers that some such transformation takes place in the body, before the fatty matter is ultimately disposed of; but he constantly speaks of the *emulsifying* power as the peculiar attribute of the pancreatic fluid, and only asserts that saponification takes place in artificial digestion, when the fluid is left for some time in contact with fatty substances; so that the Author is inclined to regard the objections above alluded-to, as having arisen from a misapprehension of M. Bernard's meaning. (See also Dr. Donaldson's account of M. Bernard's discoveries, in the "Amer. Journ. of Med. Sci.," Oct. 1851.)

† See Dr. Bright's researches on this point, in "Med.-Chir. Trans.," vol. xviii.

‡ "De Adipis Concoctione et Absorptione," Dorpat, 1850.

unlikely that the qualities of these fluids (like those of the saliva) may vary in different animals; and that the emulsifying power may be limited in the rabbit, or nearly so, to the pancreatic fluid, the quantity of fat which its natural food contains being small; whilst in the carnivorous animals, whose natural food is more oleaginous, the provision for the digestion of fatty matters may be more extensive.—Of the amount of pancreatic fluid which is daily secreted by Man, we have no other data for forming an estimate, than those afforded by the observations of Frerichs; who collected from an ass, in 45 minutes, 387½ grains, and from a large dog, in 25 minutes, 46 grains. These amounts, however, were poured forth while food was in the stomach and digestion was going on; and it is probable that, at other times, the secreting process is nearly or entirely suspended.

453. The Duodenum receives not only the Pancreatic, but also the *Biliary* secretion; and from the constancy with which this fluid is poured into the upper part of the intestinal tube, or even into the stomach itself, in all animals which have any kind of hepatic apparatus,* it seems a legitimate inference that this secretion is not purely excrementitious, but serves some important purpose in the digestive process. It is not easy, however, to state with precision what this purpose is. The result of many of the experiments which have been made to determine it, are vitiated by the fact, that the pancreatic duct in most cases discharges itself into the intestinal tube at the same point with the hepatic, and has thus been frequently involved in operations performed upon it.—As the most important constituents of Bile have been already described (§§ 67—71), and as the agency of the Liver as an assimilating and depurating organ will be more appropriately considered elsewhere (CHAPS. VIII. and XII.), we shall here limit ourselves to the consideration of what may be regarded as the best-established facts in regard to the uses of the biliary secretion in the digestive process. When its action is tested out of the body, by mingling it with the different constituents of food, it is found to exert no change upon starchy substances whilst it is fresh; though, when in a state of incipient decomposition, it acts upon them as other animal substances do. It has no action upon cane-sugar, until it has stood a considerable length of time; but then it converts it into lactic acid. This change it speedily exerts, as do nearly all other animal substances, upon grape-sugar. It has no action on albuminous substances, even when acidulated. And although it will form an emulsion with oleaginous matter, yet the emulsification is less complete than that which is effected by the pancreatic fluid alone.† Hence it appears to be deficient in anything at all similar to the peculiar ferments of the saliva, gastric juice, and pancreatic secretion; and its office in digestion must be of a different character from that of either of those fluids. The nature of this office may be partly judged-of from what takes place when fresh bile is mingled with the product of gastric digestion. The acid reaction of the latter is neutralized by the alkali of the former, and a sort of preci-

* See "Princ. of Phys., Gen. and Comp.," §§ 583–588.—The simplest condition of the Liver, such as we meet with in the higher Radiata, and in the lower Articulata and Mollusca, consists in a series of follicles lodged in the walls of the stomach and of the upper part of the intestinal tube.

† Dr. Bence Jones, in the "Medical Times," July 5, 1851.

pitation takes places (as was originally noticed by Dr. Beaumont), in which certain constituents of the bile fall down, and in which also (according to M. Bernard) the albuminous matters that have been dissolved and not yet absorbed, are for a time rendered insoluble, leaving the saccharine matters in solution, and the oleaginous floating on the top. The admixture of the bile with the chyme seems further to have the effect of checking destructive chemical changes in its composition. For M. Bernard found that when two similar pieces of meat had been immersed for three months, one in a bottle of gastric juice alone, the other in a mixture of gastric juice and bile, a strong ammoniacal odour resulting from decomposition was emitted from the former, whilst the latter was pure and free from any smell whatever. And it was remarked by MM. Tiedemann and Gmelin, that when the bile was prevented from passing into the alimentary canal, the contents of the latter were more fœtid than usual. Moreover, it is found that the admixture of bile with fermenting substances checks the process of fermentation; and M. Bernard has shown by ingeniously contrived experiments,* that this antagonistic power is exerted also in the living body. Hence we can understand how the reflux of bile into the stomach should seriously interfere with the process of gastric digestion; and how, when there is a deficient secretion of bile, or more food is swallowed than the bile provided for it can act upon, or the character of the biliary secretion itself has undergone any serious perversion, there should be a much larger amount of the putrefactive fermentation than is normal, as indicated by an evolution of flatus, and very frequently by diarrhœa. Further, the want of proper neutralization of the gastric fluid will cause the continuance of acidity in the contents of the intestinal canal, which in its turn induces a state of irritation of its mucous membrane, and a perversion of its secretions: and it is one of the beneficial results of 'alterative' medicines, employed to remedy this condition, that, by augmenting the secretion of bile, they tend to reproduce a state of neutrality in the contents of the alimentary canal. Moreover, the presence of a proper quantity of bile in the intestine appears to promote the secreting action of the intestinal glandulæ, and also to contribute to maintain the peristaltic movement of the walls of the canal; this appears alike from the tendency to constipation, which is usually consequent upon deficiency of the secretion, and from the diarrhœa which proceeds from its excess; and is confirmed by the purgative properties which inspissated ox-gall has been found to possess.

454. Notwithstanding all its uses, however, it must be admitted that the prevention of the discharge of bile into the alimentary canal is not attended with the deleterious results which might have been anticipated from it; for it has been found by the experiments of Schwann, Blondlot, and Bernard, that if the bile-duct be divided, and a tube be inserted in it in such a manner as to convey away the secretion through a fistulous orifice in the abdominal parietes, the animals thus treated may live for weeks, months, or even years,† although they usually die at last with signs of inanition. Of the quantity of bile daily poured into the alimen-

* "Amer. Journ. of Med. Sci.," Oct. 1851, p. 351.

† At the meeting of the French Academy, June 23, 1851, M. Blondlot gave the history, and an account of the post-mortem examination, of a Dog that had lived five years without the passage of any bile into the intestinal tube.

tary canal of Man, we have no other mode of forming an estimate, than by observing the quantity poured out from the bile-ducts of animals in such experiments as those just cited. Blondlot found that a dog in which he had established a fistulous opening for the discharge of the bile, secreted from 40 to 50 grammes in the twenty-four hours; whence he inferred that an adult man secretes about 200 grammes, or 7 oz. The carefully-conducted observations of Bidder and Schmidt* indicate that the rate of secretion is by no means uniform, but that it bears a certain relation to the digestive process; the quantity poured forth in a given time being greatest about 10 or 12 hours after a full meal, and then diminishing until it reaches its minimum, for which about as many more hours are required. Thus a Cat, 2 hours after a full meal of flesh, secreted at the rate of 7·5 grains of bile per hour; at the 4th hour, 9·7 grains; at the 6th hour, 11·6 grains; at the 8th hour, 12·7 grains; and at the 10th hour, 13 grains. From the 10th to the 24th hour, the secretion diminished at the rate of 4-10ths of a grain per hour; until it reached the lowest of the above amounts. The secretion is considerably diminished when food is withheld for some time; the quantity poured out after ten days' starvation being only about one-eighth of what it is when at its maximum. Still it is obvious, that although its rate is thus greatly influenced by the stage of the digestive process (which is the less to be wondered at, when it is remembered that the secretion is formed from blood that is charged with newly-absorbed and imperfectly-assimilated matters), the excrementitious character of the secretion requires that its elimination shall be constantly going on to a certain degree; but a receptacle is provided in Man, as in most others among the higher animals whose digestion is performed at intervals, for the storing-up of the fluid until it can be usefully employed in that process. The intestinal orifice of the ductus choledochus is closed by a sort of sphincter; and the fluid secreted during the intervals of digestion, not being propelled with a force sufficient to dilate this, flows back into the gall-bladder, which dilates to receive it. The presence of food in the duodenum seems to excite the walls of the gall-bladder and of the biliary ducts (which contain a large quantity of smooth muscular fibre, § 305) to a contraction sufficiently powerful to propel their contents into the intestine, in spite of the opposition of the sphincter; but whether this takes place through a reflex action of the nervous system, or through the direct stimulation of the muscular coat of the duct by the passage of alimentary matters over its orifice, we have at present no means of satisfactorily determining. It will be recollected that the gall-bladder is usually found distended with bile, in cases of death from starvation (§ 417), notwithstanding the diminution in the amount actually secreted.

455. The fluid of the Small Intestines, which is compounded by the intermixture of the biliary and pancreatic secretions, with the salivary and gastric fluids, and with the secretion of the intestinal glandulæ, appears to possess the very peculiar power of dissolving or of reducing to an absorbable condition, alimentary substances of every class; thus possessing more of the character of a 'universal solvent,' than either of these secretions has in its separate state. It completes the conversion of

* See Prof. Lehmann's "Lehrbuch der physiologischen Chemie," band ii. p. 72.

starchy into saccharine matter; and thus enables the former to supply the blood with an important pabulum for the combustive process, which is at once absorbed into the blood-vessels. It emulsifies the oleaginous matter, and thus renders it capable of being introduced into the lacteals. And it not only restores to the state of solution the albuminous compounds, which may have been precipitated by the addition of bile to the product of gastric digestion; but it also exerts a powerful solvent influence upon albuminous substances which have not been submitted to the previous agency of the gastric fluid (as has been shown by experimentally introducing pieces of meat, through a fistulous orifice, directly into the duodenum), and it thus completes the solvent process which had been very far from perfected in the stomach.* What is the precise share, however, of each of these secretions, in producing this composite result, cannot be stated with any degree of certainty; but it seems probable that the secretions of the intestinal walls have a very definite share in it.—It is obvious that the amount of each kind of alimentary substance that can be thus prepared for absorption in a given time, will vary with the amount of the secretion by whose agency this preparation is specially affected; and as there are many indications that the quantity of each that is taken up in absorption is limited, and that it bears a relation to the wants of the system, it is probable that the amount of the solvent or reducing fluid that is secreted by each glandular apparatus, is regulated (as we have seen it to be in the case of the gastric juice, § 444) by the demand set up by the nutrient operations, rather than by the amount of alimentary matter that is waiting to be digested.—The processes of digestion and conversion are probably continued during the entire transit of the alimentary matter along the small intestine, and at the same time the products of that conversion are gradually being withdrawn by absorbent action; so that, by the time it reaches the cæcum, the undigested residue contains little else than the innutritious or insoluble components of the food, together with the excrementitious portion of the bile and of other secretions. Up to this time, the contents of the canal have an alkaline reaction; but in the cæcum they again become acid; and it has been supposed that this change depends upon the secretion of a fluid analogous to the gastric juice, by the large and numerous tubular glands contained in the parietes of this part, whereby the albuminous matters still undigested might be more completely dissolved. This supposition appeared to derive weight from the fact, that the cæcum is peculiarly large in most Herbivorous animals, the 'appendix vermiformis' being also of greatly-increased dimensions, and sometimes double. But from the experiments and observations of Blondlot, it seems probable that the acid of the cæcum is rather a product of the transformation of saccharine substances in the alimentary canal, than a secretion from its walls.† Still, as this lactic acid has a solvent power for albuminous matters, which is equal, or nearly so, to that exerted by hydrochloric acid, it is by no means impossible that it may be subservient to the completion of the digestive process in the cases in question; since, the larger the proportion of the

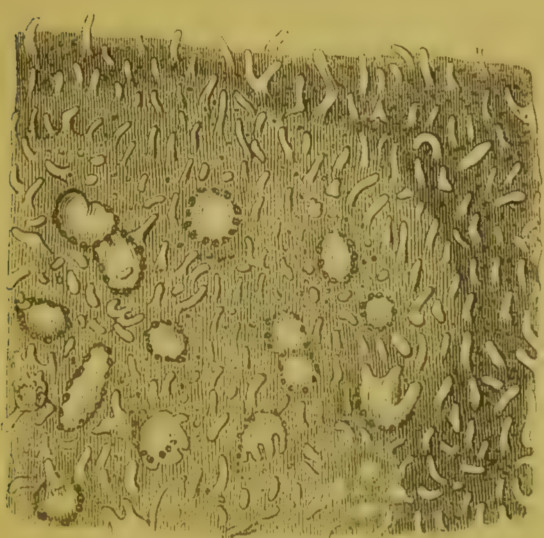
* See the account of M. Cl. Bernard's researches in the "Amer. Journ. of Med. Sci.," [Oc]t. 1851, p. 356; Zander "De Succo Enterico," inaug. diss., Dorpat, 1850; and Frerichs, [Art]. *Verdauung*, in "Wagner's Handwörterbuch."

† See his "Traité analytique de la Digestion," p. 103.

aliment composed of saccharine matters, the greater will be the importance of a thorough extraction of its albuminous constituents.

456. The walls of the lower part of the Small Intestine are beset with elevated patches, that are formed by the aggregation of the bodies known as the 'Peyerian glandulæ;' bodies of a similar kind, however, also occur separately, and are then known as the 'glandulæ solitariæ.' The 'glands of Peyer,' when examined in a healthy mucous membrane, present the appearance of circular, white, slightly raised spots, about a line in diameter; over which the membrane is usually less set with villi, and very often entirely free from them. Each of these white spots, of which a large number are contained in the agminated glands, is surrounded by a zone of openings like those of the follicles of Lieberkühn, which lead (as do those) into tubular cæca (Fig. 95). Not unfrequently, however, the centre of the spot exhibits a very definite opening, which may be compared to the pupil of the eye; and this opening, though formerly supposed to be abnormal, appears from the observations of Profrs. Krause* and Allen Thomson† to be the normal condition of the body at a certain stage of its development. In the Pig, on which the greater number of Dr. A. Thomson's observations were made, some patches often present no openings, whilst in others almost all the cavities are open and empty; and in a third set, open and closed vesicles are irregularly disposed in the same patch (Fig. 96). The open vesicles were observed more frequently in the ileum than in the upper part of the intestine; and it appeared to be in those parts of the intestine which contained the more fluid, dark-coloured, and bilious

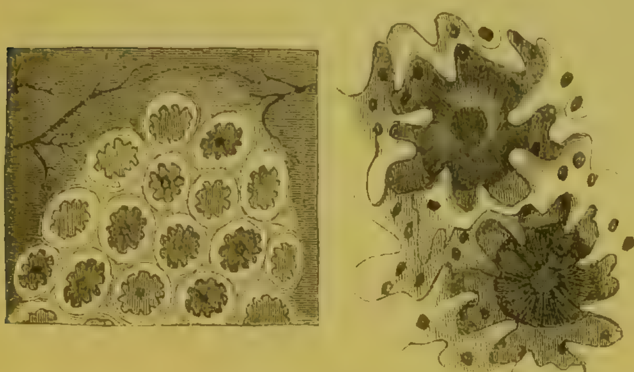
Fig. 95.



Portion of one of the patches of *Peyer's Glands*, from the end of the Ilium, moderately magnified; the villi are also displayed.

Fig. 96.

A B



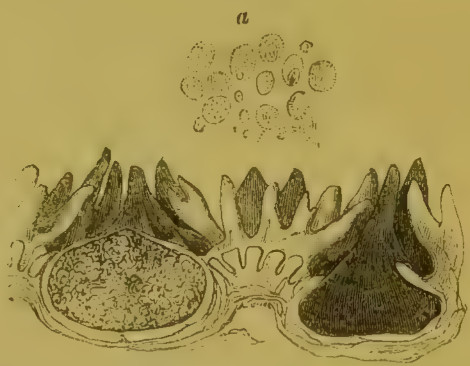
A, Portion of a patch of *Peyerian Glandulæ* from the ileum of the Pig, as seen from the deep surface, the serous, muscular, and areolar coats having been dissected off; the darker vesicles are open and empty, the paler closed and full; magnified 3 diameters:— B, two of these vesicles, viewed from the inner surface of the intestine, one of them closed and full, the other open and empty, with villi and apertures of mucous follicles in their neighbourhood; magnified 15 diameters.

* "Müllers's Archiv.," 1837 and 1839.

† "Annals of Anatomy and Physiology," No. 1, p. 35.

matter, that the open vesicles were almost invariably found; while in those parts of the gut which contained a light-coloured chymous or chylous mass, which were more contracted, and in which the coats appeared thickened by the imbibition of chyle, the vesicles were all closed and full of their usual contents. These consist of minute granular cells, mixed with molecules of various sizes (Fig. 97); and it has not seemed an unreasonable supposition, that each of these bodies might be regarded as a distinct glandular vesicle, which dehisces and discharges its contents, when these are prepared for being set free; and that it is then succeeded by a new vesicle developed *de novo* from a parent-cell (§ 235). — A new view of the character of the Peyerian bodies, however, has lately been put forth by Brücke; who affirms that they are always closed in their normal condition, and maintains that they are appendages to the Absorbent system, its trunks being filled by injections made to penetrate from them, and their cellular contents being precisely conformable in aspect and character to those of the mesenteric glandulæ.* It has been further demonstrated by Prof. Frei, that the interior of each vesicle is traversed by a set of capillary vessels, which radiate from the periphery towards the centre, and then return by loops;† a structure which is found also in the 'Malpighian bodies' of the Spleen, the vesicles of the Thymus, &c. Hence these anatomists urge that the so-called 'Peyerian glandulæ' must be regarded as instruments for the elaboration of the chyle, which is conveyed to them by the very delicate absorbents that originate in the villi, and is carried-off by the larger trunks which then pass into the mesentery.‡—The walls of the Large Intestine contain

Fig. 97.




Vertical section of two of the *Peyerian Glandulæ* from the ileum of the Pig, one of them closed and full, the other open and empty, with their neighbouring villi; magnified 15 diameters:—*a*, cellular contents of the vesicle; magnified 250 diameters.

* See his Memoir 'Ueber den Bau und die physiologische Bedeutung der Peyerischen Drüsen,' in "Denkschriften der kaiserlichen Akademie der Wissenschaften," Wien, 1850; and an abstract of it in the "Edinb. Monthly Journ.," Nov. 1850.

† See Prof. Kölliker's "Mikroskopische Anatomie," band ii. § 171.

‡ In the above statements, the Author has considered it preferable to place before his readers the results of actual observations, rather than to indulge in any hypothesis of his own. Taking for granted the doctrine generally admitted amongst modern anatomists and physiologists, that the Peyerian vesicles are glandulæ discharging their product into the intestinal tube,—combining this with the doctrine of which also there appeared to his mind to be adequate evidence, that the proper *fæcal* matter is a secretion *sui generis*, and not a mere product of the decomposition of the contents of the alimentary canal,—and taking into account the correspondence in position between the principal aggregations of Peyerian glandulæ and the assumption of the fæcal character by the undigested residue of the food,—he had considered himself justified in advancing it as probable, that the Peyerian glandulæ are the special instruments for the elimination of decomposing matter from the blood, and that it is their function to discharge this excrementitious product into the alimentary canal. And the tendency to ulceration of these follicles, which shows itself in typhoid fever and other 'poison-diseases,' was cited by Dr. C. J. B. Williams ("Principles of Medicine," 2nd edit. p. 248) in confirmation of this view. Having himself repeatedly met with the follicles in the *open* condition, like Dr. Allen Thomson, and having been well convinced that this is a normal

a considerable number of glandulæ, which closely resemble the 'glandulæ solitariæ' of the higher part of the canal; these, however, are so much more frequently open than closed, that the latter condition was not recognized until pointed out by Dr. Baly.* It can scarcely be doubted that these are secreting organs, destined to pour the product of their activity into the alimentary canal; but whether this product be the peculiar mucus with which the coats of the large intestine are covered, or consist of the proper fæcal matter, or be something different from either, has not yet been determined.

457. The undigested residue of the food, mingled with the products of secretion that have been poured into the alimentary canal, gradually acquires, in the Large Intestine, the ordinary consistency of fæces, through the continuance of the absorbent process, whereby the superfluous fluid is removed. The condition of the undigested residue has been particularly studied by Dr. Rawitz, who examined microscopically the products of the artificial digestion of different kinds of aliment, and the contents of the fæces of animals that had eaten the same articles. "The general results of his examinations, as regards *animal* food, show that the muscular tissue breaks up into its constituent fasciculi, and that these again are divided transversely; gradually the transverse striæ become indistinct and then disappear; and finally the sarcolemma seems to be dissolved, and no trace of the tissue can be found in the chyme, except a few fragments of fibres. These changes ensue most rapidly in the flesh of fish and hares, less rapidly in that of poultry and other animals. The fragments of muscular tissue which remain after the continued action of the digestive fluid, do not appear to undergo any alteration in their passage through the rest of the intestinal canal; for similar fragments may be found in fæces, even twenty-four hours after the introduction of the meat into the stomach. The cells of cartilage and fibro-cartilage, except those of fish, pass unchanged through the stomach and intestines, and may be found in the fæces. The interstitial tissues of these structures are converted into pulpy textureless substances in the artificial digestive fluid, and are not discoverable in the fæces. Elastic fibres are unchanged in the digestive fluid.† Fatty matters are also unchanged; fat-cells are sometimes found quite unaltered in the fæces; and crystals of cholesterin may usually be obtained from fæces, especially after the use of pork-fat. —As regards *vegetable* substances, Dr. Rawitz states that he frequently found large quantities of cell-membranes unchanged in the fæces; also starch-cells, deprived of only part of their contents. The green colouring principle, chlorophyll, was usually unchanged. The walls of the sap-

state, he finds it difficult to receive the doctrine of Brücke (espoused though it has been by Prof. Kölliker) as expressing the whole truth on this subject, which is one that is well deserving of further investigation.

* "Medical Gazette," March, 1847.

† It has been pointed out to the Author by his friend Mr. Quekett, that elastic fibres are occasionally to be met with in the Human fæces, which present an appearance (probably resulting from incipient decomposition) closely resembling that which is normal in the ligamentum nuchæ of the Giraffe (§ 221 *note*). So distinct, indeed, does the transverse division then become, that these fibres, when peculiarly abundant (as they are in the fæces of persons who have for some time been living upon mutton chops, and have not put aside the segment of the aorta which each chop includes), have actually been mistaken for a Confervoid growth in the fæces.

vessels and spiral vessels were quite unaltered by the digestive fluid, and were usually found in large quantities in the fæces; their contents, probably, were removed."*—Besides the undigested residue of the food, the microscope enables us to recognise the brown colouring-matter of the bile, epithelium-cells and mucus-corpuscles, and various saline particles, especially those of the ammoniaco-magnesian phosphate,† whose crystals are well-defined; most of which are derived from the secretions. The quantity of fæcal discharge which is daily passed by an adult, seems to average from 4 to 6 oz.; but this contains 75 per cent of water; so that the dry solid matter thus evacuated is not above 1 oz. or $1\frac{1}{2}$ oz.—The following is the result of the proximate analysis of the fæces of an individual in good health, who had taken the ordinary diet of this country; as given by Dr. Percy.‡

| | |
|---|---|
| Substances soluble in ether (brownish yellow fat) | 11·95 |
| „ „ alcohol of ·830 | 10·74 |
| „ „ water (brown resinoid matter) | 11·61 |
| Organic matter insoluble in the above menstrua | 49·33 |
| Salts soluble in water | 4·76 |
| Salts insoluble in water | 11·61 |

Ultimate analysis of the same fæces gave the following as the proportion of the components of the Organic constituents; Carbon 46·20, Hydrogen, 6·72, Nitrogen and Oxygen, 30·71, Ash, 13·37.—The mineral ash of fæcal matter has been examined by Enderlin;§ who has given the following as the proportion of its ingredients.

| | | |
|---|---|---|
| Chloride of sodium and alkaline sulphates | 1·367 | Soluble in water. |
| Bibasic phosphate of soda | 2·633 | |
| Phosphates of lime and magnesia | 80·372 | Insoluble in water. |
| Phosphate of iron | 2·090 | |
| Sulphate of lime | 4·530 | |
| Silica | 7·940 | |

From the later inquiries of Lehmann and others, however, it appears that the proportion of salts often considerably exceeds that given by Dr. Percy, ordinarily rising to 23 per cent, and even to $30\frac{1}{2}$ or $31\frac{1}{2}$ per cent, when an abundant meat diet has been consumed. The potash generally predominates greatly over the soda, but especially when the diet has chiefly consisted of muscular flesh.—Of the degree in which the bile, as a whole, enters into the composition of the fæces, it is difficult to speak with precision. Its colouring and its fatty matter are undoubtedly present; but scarcely any traces of choleic acid, or of either of its conjugated compounds, or of their soda-base, can be detected; so that the proper biliary matter must either have undergone decomposition, so as to be no longer

* The above passage is quoted from Messrs. Kirkes and Paget's "Hand-book of Physiology," in which it is derived from the Memoir by Dr. Rawitz "Ueber die Einfachen Nahrungsmittel," Breslau, 1846.

† The presence of this salt in the fæces was maintained by Schonlein to be pathognomonic of typhus; but more recent and correct observations have shown that this view is fallacious. Crystals of this salt sometimes occur in perfectly normal fæces; and in those cases in which the secreted fluids and the contents of the intestine readily undergo decomposition, as in typhus, cholera, and certain forms of dysentery, they are found in large numbers and of considerable size.

‡ Simon's "Animal Chemistry" (translated by Dr. Day), vol. ii. p. 375.

§ "Ann. der Chem. und Pharm.," 1844.

recognizable, or else it must have been reabsorbed. The latter is the idea now usually entertained, although Valentin has endeavoured to show that the proper *fœcal* matter is chiefly derived from decomposed constituents of the bile; a more probable source for this, however, will be presently offered. The indications of the presence of bile are more distinct, when the fæces have remained for only a short time in the large intestine, and when there has consequently been less time for its reabsorption. In the fæcal discharges which result from the action of mercurials, large quantities of biliary matter may be detected, very little changed.

458. Although it cannot be stated with certainty what is the precise portion of the Glandular apparatus connected with the Intestinal canal, which is concerned in the elimination of that peculiarly putrescent matter which gives to the fæces their characteristic odour, yet it may be stated almost with certainty that this matter is *not* derived from the decomposition of the undigested residue of the food. For, in the first place, this residue consists of matters whose very inaptitude for undergoing chemical change is the source of their indigestibility; and it is scarcely possible, therefore, to imagine that in so short a period they should acquire a character so peculiarly offensive. But further, we observe that fæcal matter is still discharged, even in considerable quantities, long after the intestinal tube has been completely emptied of its alimentary contents. We see this in the course of many diseases, when food is not taken for several days, during which time the bowels have been completely emptied of their previous contents by repeated evacuations; and whatever then passes, in addition to the biliary and pancreatic fluids, must be derived from the intestinal walls themselves. Sometimes a copious flux of putrescent matter continues to take place spontaneously; whilst it is often produced by the agency of purgative medicine. The "colliquative diarrhœa," which frequently comes on at the close of exhausting diseases, and which usually precedes death by starvation, appears to depend, not so much upon a disordered state of the intestinal glandulæ themselves, as upon the general disintegration of the solids of the body, which calls them into extraordinary activity, for the purpose of separating the decomposing matter which has accumulated in it to a most unusual amount (§ 418). These views (which have long been taught by the author) derive a remarkable confirmation from the experiments of Prof. Liebig on the production of artificial fæcal matter. For he has ascertained that if albuminous or gelatinous compounds be heated with solid hydrate of potash, and the heat be continued until the greater part or the whole of the nitrogen has been dissipated as ammonia, and hydrogen begins to be given off, the residue, when supersaturated with dilute sulphuric acid, and distilled, yields a liquid containing acetic and butyric acids, and possessing in a very intense degree the peculiar and characteristic odour of human fæces. The odour varies according to the substance employed; and in this way all varieties of fæcal smell may be obtained. As the action of caustic potash at a high temperature is simply a limited or incomplete oxidation or combustion, this curious result confirms the view which had been previously put forth by Prof. Liebig, that the proper fæcal matter is the product of the imperfect oxidation which a portion of the histogenetic constituents of the food undergo in the course of their regressive metamorphosis, being comparable to the soot or lamp-black of a furnace or lamp. It is further urged by

him, that the condition of the fæces differs in many particulars from that of substances in a state of fermentation or putrefaction; that their peculiar odour is entirely unlike any that is generated by the ordinary decomposition of organic compounds, whether azotized or non-azotized; and that, by contact with air, they themselves undergo a sort of fermentation or putrefaction, in which their peculiar fœtor disappears,—a fact, as he justly remarks, which is full of significance.* This view is of great practical importance; for if it be true that the intestinal canal receives and discharges the products of the secreting action of a glandular apparatus, whose special function is the elimination of certain products of decomposition from the blood, the facility with which we can stimulate this to increased action by certain kinds of purgative medicine, gives us a most valuable means of augmenting its depurative action. Seeing, as no observant Medical Practitioner can avoid doing, how frequently Nature herself employs this means of eliminating morbific matter from the system,—as shown by the immense relief often given by an attack of diarrhœa,—we may look upon this apparatus as one which, like the Liver, the Kidney, or the Skin, may frequently with propriety be stimulated by medicines that have a special action upon it, and one through which some morbific matters may be got rid of more certainly and more speedily than through any other channel.—It is not intended by these observations to encourage the system of violent and indiscriminate purgation; but to show that purgatives, judiciously administered, often constitute our best means of eliminating injurious matters from the system.

## CHAPTER VIII.

### OF ABSORPTION AND SANGUIFICATION.

#### 1. *Of Absorption from the Digestive Cavity.*

459. So long as the Alimentary matter remains in the digestive cavity, however perfect may be its state of preparation, it is as far from being conducive to the nutrition of the system, as if it were in contact with the external surface. It is only when absorbed into the vessels, and carried by the circulating current through the very substance of the body, that it becomes capable of being appropriated by its various tissues and organs. Among the higher Invertebrata, we find the reception of alimentary matter into the circulating system to be entirely accomplished through the medium of the *Blood-vessels*, which are distributed upon the walls of the digestive cavity. But in the Vertebrata, we find an additional set of vessels interposed between the walls of the intestine and the sanguiferous system; for the purpose, as it would seem, of taking up certain components of the nutritive matter, of which part at least are not in a state of perfect solution, and of preparing them for being introduced into the current of the blood. These are the *Absorbents* of the intestinal walls; of which those that are found, after the performance of the digestive process, to contain the white

* See Prof. Liebig's "Animal Chemistry," 3rd edit. pp. 148–154.

opalescent fluid known as 'chyle,' are distinguished as *lacteals;* while the remainder, like the absorbents of the system generally, are known as *lymphatics.* The distinction is a purely artificial one; for the 'lacteals' are the 'lymphatics' of those parts of the intestinal walls which they supply, as is shown by the fact that, during the intervals of the digestive process, they contain a transparent fluid in all respects similar to the 'lymph' of other parts. The Absorbents form a minute plexus beneath the mucous lining of the alimentary canal along its whole extent; but in the small intestine they enter the villi, at the extremities of which, indeed, they may be said to commence. Those only are entitled to the designation of 'lacteals,' which originate from the intestinal canal below the point at which the biliary and pancreatic ducts pour their contents into it; for above that point, the fatty constituents of the alimentary matter are not in a state of sufficiently fine division to enter them; and the absorbed fluid is consequently pellucid, instead of possessing the milky aspect. Thus, then, we are to consider the *lacteal* portion of the Absorbent system, to be that part of it which is specially adapted, by its prolongation into the villi, for the reception of an oleaginous fluid; which we shall presently see to be taken up from the contents of the alimentary canal, and to be prepared for entrance into the absorbents, by a set of peculiar cells developed at the radical extremities of those organs (§ 461).

FIG. 98.


Vessels of an *Intestinal Villus* of a *Hare,* from a dry preparation by Döllinger: — *a, a,* veins filled with white injection; *b, b,* arteries injected red.

460. The general structure of the *Villi* of the Intestinal mucous membrane has been already described (§§ 228, 234); but the peculiar disposition of their component structures must here be more minutely noticed. —Each villus appears ordinarily to contain but a single lacteal tube which occupies its centre; in the larger villi, however, two or even more trunks are sometimes discernible (Fig. 99, A). The mode in which this tube commences, near the extremity of the villus, has not yet been precisely made out; but it seems probable that it originates in a plexus, formed by the anastomosis of branches into which it subdivides. This much, however, is quite certain, that the lacteals do *not* commence by open orifices on the internal surface of the intestinal tube, as they were formerly supposed to do. Each villus is also furnished with a minute plexus of capillary vessels, which lies near its surface; these sometimes pass between a single arterial and venous twig, as in the villus of the Hare (Fig. 98), but are sometimes supplied by several distinct twigs, as in the villi of Man (Fig. 22); the particular arrangement of the vessels, the form of the plexus, &c., differing considerably in different animals, and even in different portions of the intestine of the same individual. From the facts to be presently stated, it will be obvious that these blood-vessels are not less

actively concerned in the absorbent functions, than are the lacteals themselves; and there is evidence, moreover, that the circulation of blood through them is essential to the introduction of chyle into the absorbents.* Hence some have supposed that the contents of the lacteals are first imbibed by the blood-vessels, and are afterwards eliminated from them by a kind of glandular action on the part of the absorbents; but of this there is no adequate evidence; and it seems more probable that the constant supply of blood is required for that peculiar cell-action, to which the selection of the materials of the chyle is due.—The curious fact has recently been substantiated by Prof. Kölliker,† that the villi contains numerous muscular fibre-cells (§ 305), and that they present themselves in very different degrees of contraction and extension. This observation confirms the statement formerly made by M. Lacauchie ‡ as to the existence of contractile tissue in the villi, which statement was based on the contraction which he had observed them to undergo after their removal from the body; and also the yet more remarkable assertion of MM. Gruby and Delafond, that rhythmical movements of contraction and extension in different directions take place in the villi whilst absorption is going on,§ which have an important influence on the propulsion of the fluids contained within their vessels.

461. When the Villi are examined at such a period after a meal containing oleaginous matters, as has sufficed for its partial digestion, their lacteals are seen to be turgid with chyle (Fig. 99, A); and the extremity

FIG. 99.


Extremity of *Intestinal Villus:* seen at A, during absorption, and showing absorbent cells and lacteal trunks, distended with chyle; at B, during interval of digestion, showing the supposed peripheral network of lacteals.

of each lacteal appears to be imbedded in a collection of globules presenting an opalescent appearance, which gives to the end of the villus a somewhat mulberry-like form. It was supposed by Prof. Goodsir,|| by whom this appearance was first observed, that these globules are cells developed *within* the basement-membrane, during the act of absorption, from what he considered to be granular germs visible in the same situation during the intervals of the process (B); and that these cells, drawing into themselves during their growth certain of the nutritive materials contained in the intestinal canal, are thus the real agents

* See especially the experiments of Mr. Fenwick in the "Lancet," Jan. and Feb., 1845.
† "Mikroskopische Anatomie," band ii. § 168.
‡ "Etudes Hydrotomiques et Micrographiques," Paris, 1844, p. 50.
§ "Comptes Rendus," 1842, p. 1199; and 1843, p. 1195.
|| "Edinb. New Phil. Journ.," July, 1842; and "Anatomical and Pathological Observations," pp. 5-10.

in the *selection* of the substances which are to be introduced into the lacteals, delivering them to these, by the rupture or deliquescence of their walls, so soon as their own term of life is ended. It was further held by Prof. Goodsir, that the epithelium-cells covering the extremities of the villi fall off during the process of absorption, so as to leave the villi more free to imbibe the fluids in contact with their surface; and thus that a new set of absorbent cells is developed with every recurrence of the act of absorption, and a new set of protective epithelium-cells in the subsequent interval. These views, however, though correctly indicating the fact that the elements of chyle are introduced into the lacteals by the intermediation of cells, have been shown to be erroneous so far as regards the nature of these cells; which several excellent observers* agree in regarding as the proper epithelium-cells of the villi,—these not being thrown off, as Prof. Goodsir believed, but so completely changing their aspect in consequence of the imbibition of oleaginous fluid (Fig. 100), that they cease to be recognizable as such, unless their intermediate stages be traced. The epithelium-cells of the villi may frequently be observed (as formerly mentioned) to be connected at their free extremities by something like a continuous membrane (Fig. 20); and it was doubtless this which was mistaken by Prof. Goodsir for the proper basement-membrane that underlies the epithelium-cells.—It may, then, be stated with some confidence, that the epithelium-cells covering the extremities of the villi are the real instruments in the selection and absorption of the materials of the chyle; and that, drawing these into their own cell-cavities, they subsequently deliver them up to the lacteals, by which they are carried towards the centres of the circulation. And further, that although it may be true that the epithelium-cells are sometimes cast-off in considerable quantities, in certain disordered states of the mucous membrane (as in cholera), yet that there is no evidence of its being thus exuviated in health; the appearances which have led to the idea that such exuviation is a regular occurrence, being partly dependent upon the facility with which the villi are denuded of them by maceration or manipulation.

Fig. 100.


Extremity of an *Intestinal Villus* during absorption:—*a*, marginal layer of epithelium-cells; *b*, epithelium-cells turgid with oleaginous matter; *c*, adherent oil globules.

462. In regard to the degree in which the function of Nutritive Absorption is performed by the Lacteals and by the Sanguiferous system respectively, considerable difference of opinion has prevailed. When the Absorbent vessels were first discovered, and their functional importance was perceived, it was imagined that the introduction of alimentary fluid

* See MM. Gruby and Delafond, in "Comptes Rendus," 5 Juin 1843; Küss, in "Gaz. Méd. de Strasbourg," No. 2, 1846; E. H. Weber, in "Müller's Archiv.," 1847; Kölliker, "Mikroskopische Anatomie," band ii. § 169; and Bennett, in "Edinb. Monthly Journal," March, 1852, p. 283.

into the vascular system took place by them alone. A slight knowledge of Comparative Anatomy, however, might have sufficed to correct this error; since no lacteals exist in the Invertebrated animals, the function of Absorption being performed by their mesenteric blood-vessels only, whence it is evident that these do possess the power of absorption: and it is scarcely to be supposed that they should not exercise this power in Vertebrated animals also, since their disposition on the walls of the intestinal cavity is obviously favourable to it. On the other hand, the introduction of a new and distinct system of vessels would seem to indicate, that they must have some special purpose; and there can be no doubt that the absorption of a particular kind of nutritive matter is that for which they are designed.—That Absorption is effected, to a very considerable amount, by the agency of the Blood-vessels, is shown by the readiness with which aqueous fluids, and even alcohol, are taken up from the parietes of the stomach, and are carried into the general circulation. Thus in a case of extroversion of the bladder, observed by Mr. Erichsen,* in which the urinary secretion could be collected immediately on its passing from the kidney, when a solution of ferrocyanide of potassium was taken into the stomach, this salt was detected in the urine in one instance within 1 minute, and in three other instances within $2\frac{1}{2}$ minutes. In all these cases, however, the stomach may be presumed to have been empty, and the vascular system in a state of aptitude for absorption; since the experiments were made either after a long fast, or at least four hours after a light meal. When, on the other hand, the salt was introduced into the stomach soon after the ingestion of alimentary substances, a much longer period elapsed before it could be detected in the urine; thus when a substantial meal had been taken two hours previously, the interval was 12 minutes; when tea and bread-and-butter had been taken one hour previously, the interval was 14 minutes; a similar meal having been taken twenty-four minutes previously, the interval was 16 minutes; when only two minutes had passed since the conclusion of such a meal, the interval was 27 minutes; and when a solid meal had been concluded just before the introduction of the salt, the interval was 39 minutes.†—These facts are of great importance, in showing the very

* "Medical Gazette," vol. xxxvi. p. 363.

† The great rapidity with which soluble salts, introduced into the stomach, make their appearance in the urine, has led M. Cl. Bernard to think that some more direct channel must exist for their passage from the stomach to the kidneys, than that which the ordinary current of the sanguiferous circulation affords. And he has advanced the extraordinary doctrine, that whilst absorption is going on, there is a constriction of the vena cava above the entrance of the hepatic vein, whereby a *reflux* of the blood discharged by it takes place, so that it passes into the *renal* vein, without reaching the heart. And he asserts that a peculiar thickening of the muscular coat exists in the upper part of the vena cava, whereby its contraction is occasioned; also that there are (in the horse at least) direct passages by which a part of the portal blood may be discharged into the vena cava, without passing through the liver. ("L'Union Médicale," 1849, No. 115).—Now, in the first place, this hypothesis is not necessary to explain the facts; for, as will be shown hereafter (§ 509), there is evidence of the transmission of substances to *other* parts, with at least as much rapidity as is indicated by their appearance in the urine. And, in the second place, if the supposed reflux really took place, it must affect the whole venous circulation of the trunk and lower extremities, except such as the vena azygos and a few other small channels could provide for; and must occasion (to make good the conditions of the problem) not merely a *stagnation*, but an absolute *reflux*, so that the veins are metamorphosed into arteries, and the arteries into veins. How the *vis a tergo*, originally derived from the heart, can thus be strong enough at the very end

marked influence which the state of the *stomach* exercises upon the absorption of matters introduced into it. Not less important, however, is the state of the *vascular system* in regard to turgescence or emptiness; for it was found by Magendie, that when he had injected a considerable quantity of water into the veins of a dog, poison was absorbed very slowly; whilst if he relieved the distension by bleeding, there was speedy evidence of its entrance into the circulation.—The rapidity with which not only aqueous but alcoholic liquids introduced into the stomach may pass into the general circulation, has been shown by the experiments of Dr. Percy;* who found that when strong alcohol was injected into the stomach of dogs, the animals would sometimes fall insensible to the ground *immediately* upon the completion of the injection, their respiratory and cardiac movements ceasing within two minutes; and that on post-mortem examination in such cases, the stomach was nearly empty, whilst the blood was highly charged with alcohol; thus rendering it highly probable, that not merely the final destruction of nervous power, but the immediate loss of sensibility, was due to the action of alcoholized blood upon the nervous centres.—Finally, numerous experiments have been made by various physiologists, which have demonstrated the absorption of alimentary and other substances from the walls of the Stomach; these substances having been prevented from passing into the intestine, by a ligature around the pylorus. Now as the Absorbent system does not present that peculiar arrangement in the coats of the stomach, which it does in those of the intestinal tube, there can be little doubt that the introduction of such substances into the system must be effected chiefly, if not entirely, through the medium of its capillary Blood-vessels.

463. That the Blood-vessels of the Intestinal tube, also, largely participate in the introduction of soluble alimentary matter into the system, has been clearly proved by various observations upon the constitution of the blood of the mesenteric veins (§ 167); these having shown, that after the digestion of albuminous and farinaceous or saccharine substances, albuminose, dextrin, grape-sugar, and lactic acid are detectible in that fluid, whose usual composition is greatly altered by the presence of these substances, as well as by the augmented proportion of water which it contains. We may consider the Sanguiferous vessels, then, as affording the usual channel by which a large part of the nutritive materials are introduced into the system; but these are not allowed to pass into the general current of the circulation, until they have been subjected to an important *assimilating* process, which it appears to be one great office of the Liver to perform, whereby they are rendered more fit for the purposes they are destined to serve in the economy. Of this we shall presently have to speak (§ 472).—But the absorbent power which the blood-vessels of the Alimentary canal possess, is not limited to alimentary substances; for it is through them almost exclusively, that soluble matters of every other description are received into the circulation. This, which may now be considered a well-established fact, was first clearly shown by the carefully-

of the systemic circulation, not merely to neutralize, but actually to overcome, the force which it exercises almost close to the heart, M. Bernard has not informed us.

* "Experimental Inquiry concerning the Presence of Alcohol in the Ventricles of the Brain," p. 61.

conducted experiments of MM. Tiedemann and Gmelin,* who mingled with the food of animals various substances, which, by their colour, odour, or chemical properties, might be easily detected in the fluids of the body: after some time the animal was examined; and the result was, that unequivocal traces of such substances were not unfrequently detected in the venous blood and in the urine, whilst it was only in a very few instances that any indication of them could be discovered in the chyle. The colouring matters employed were various vegetable substances; such as gamboge, madder, and rhubarb; the odorous substances were camphor, musk, asafœtida, &c.; while, in other cases, various saline bodies, such as chloride of barium, acetate of lead and of mercury, and some of the prussiates, which might easily be detected by chemical tests, were mixed with the food. The colouring matters, for the most part, were carried out of the system, without being received either into the veins or lacteals; the odorous substances were generally detected in the venous blood and in the urine, but not in the chyle; whilst of the saline substances, many were found in the blood and in the urine, and a very few only in the chyle. A similar conclusion might be drawn from the numerous instances, in which various substances introduced into the intestines have been detected in the blood, although the thoracic duct had been tied; but these results are less satisfactory, because even if there be no direct communication (as maintained by many) between the lacteals and the veins in the mesenteric glands, the partitions which separate their respective contents are evidently so thin, that transudation may readily take place through them.

464. This Absorption by the Blood-vessels is a simply *physical* operation, depending upon the relative consistency and miscibility of the blood and of the liquids to be absorbed, and upon the rapid movement of the blood through the vessels. Where the contents of the alimentary canal are of less specific gravity than the blood, and are capable of readily mingling with it, an endosmotic current will be established, through the delicate parietes of the blood-vessels and their thin investments, between the two liquids, the former passing towards the other; and in this mode, albuminous, gelatinous, saccharine, saline, and other soluble substances may be caused to enter the blood, if their solution be not too concentrated. But if their density be equal to that of the blood, or nearly so, little or no absorption is likely to take place; and one purpose which is answered by the very copious discharge of aqueous fluid into the alimentary canal, during the operation of digestion, is obviously the reduction of the density of the solution to a favourable point. If, again, the density of the contents of the alimentary canal should exceed that of the blood, an endosmotic current might perhaps be established in the opposite direction; but their dilution would probably be effected so speedily, that little of the contents of the blood-vessels would be thus drawn forth, more especially as animal membranes appear to have a special power of resisting the passage of Albumen, whilst they give free transmission to Albuminose.†—That the movement of blood in the vessels will vastly increase

* "Versuche über die Wege auf welchen Substanzen aus dem Magen und Darmkanal ins Blut gelangen," Heidelberg, 1820.

† It is considered by Liebig that the purgative effects of concentrated saline solutions are to be accounted-for on this principle,—the establishment of an endosmotic current *from*

the rate of endosmotic absorption, is easily proved experimentally; and this it is which constitutes the main difference between the living and the dead subject.*

465. It is a very remarkable fact, which has recently been fully substantiated, that not merely soluble matters, but insoluble substances in a state of minute division, may find their way from the alimentary canal into the current of the circulation. Thus it was found by Oesterlen† that particles of finely-divided charcoal, introduced into the alimentary canal, could be distinguished in the blood of the mesenteric veins; and similar results have been obtained by Eberhard, and by Mensonides and Donders, not only with charcoal, but also with sulphur and even with starch, the latter substance being at once detectible in the blood by the iodine-test. It is doubtful whether these particles are taken-up by the lacteal system; though Donders seems of opinion, from finding them deposited in the lungs rather than in the liver, that the former is their more usual channel of entrance.‡ How they find their way through the walls of the vessels, however, is at present a complete mystery.

### 2.—*Absorption from the Body in general.*

466. The Mucous Membrane of the alimentary canal is by no means the only channel through which nutritive or other substances may be introduced into the circulating apparatus from external sources. The *Lymphatic* system is present in all animals which have a *lacteal* system; and the two, as already pointed out, evidently constitute one set of vessels. The Lymphatics, however, instead of commencing on the intestinal walls, are distributed through most of the vascular tissues of the body, and especially in the Skin; but their number bears no proportion whatever to the vascularity of the several tissues, or to the amount of interstitial change which these undergo; and it is remarkable that the Nervous centres should be (so far as is yet known) entirely destitute of them, and that they should be so scanty in the interior of Muscles, as to suggest that they belong rather to the connective areolar tissue than to the muscular substance itself (§ 308). Their origins cannot be clearly traced; but they seem in general to form a plexus in the substance of the tissues, from which the convergent trunks arise. After passing, like the lacteals, through a series of glandular bodies (the precise nature of which will be presently considered, § 473), they empty their contents into the same receptacle with the lacteals; and the mingled products of both pass into the Sanguiferous system.—We find in the Skin, also, a most copious distri-

instead of *towards* the circulating system. It is difficult, however, thus to account for all the phenomena of saline purgation; and the Author greatly doubts the validity of the explanation.—It may, however, be applied with more probability, to the fact of which the Author was assured by the late Dr. Prout; viz., that having fed a dog upon *pure* starch, he had found albumen in the duodenum. On this fact Dr. Prout much relied as a proof of the *convertibility* of starch into albumen,—an idea which would now be universally condemned by Organic Chemists; but it does not seem difficult to believe, that the presence of a viscid mass of half-digested starch might have determined a transudation of albumen from the blood-vessels by endosmosis.

* On the whole of this subject, see the Author's "Princ. of Phys., Gen. and Comp.," CHAP. XI.

† "Heller's Archiv.," 1847.

‡ "Henlé's Zeitschrift," 1851.

bution of capillary blood-vessels, the arrangement of which is by no means unlike that of the blood-vessels of the alimentary canal; and its surface is further extended by the elevations that form the sensory papillæ (Fig. 90), which are in many points comparable to the intestinal villi, although their special function is so different.

467. In the lowest tribes of animals, and in the earliest condition of the higher, it would seem as if Absorption by the *external surface* is almost equally important to the maintenance of life, with that which takes place through the internal reflexion of it forming the walls of the Digestive cavity. In the adult condition of most of the higher animals, however, the special function of the latter is so much exalted, as usually to supersede the necessity of any other supply; and the function of the cutaneous and pulmonary surfaces may be considered as rather that of exhalation, than of absorption.* But there are peculiar conditions of the system, in which the imbibition of fluid through these surfaces is performed with great activity, supplying what would otherwise be a most important deficiency. It may take place either through the direct application of fluid to the surface, or even through the medium of the atmosphere, in which a greater or less proportion of watery vapour is usually dissolved. This absorption occurs most vigorously, when the system has been drained of its fluid, either by an excess of the excretions, or by a diminution of the regular supply.

468. It may be desirable to adduce some individual cases, which will set this function in a striking point of view; and those may be first noticed, in which the Absorption took place through the contact of *liquids* with the skin. It is well known that shipwrecked sailors, and others, who are suffering from thirst, owing to the want of fresh water, find it greatly alleviated, or altogether relieved, by dipping their clothes into the sea, and putting them on whilst still wet, or by frequently immersing their own bodies.†—Dr. Currie relates the case of a patient labouring under dysphagia in its most advanced stage; the introduction of any nutriment, whether solid or fluid, into the stomach, having become perfectly impracticable. Under these melancholy circumstances, an attempt was made to prolong his existence, by the exhibition of nutritive enemata, and by immersion of the body, night and morning, in a bath of milk and water. During the continuance of this plan, his weight, which had previously been rapidly diminishing, remained stationary, although the quantity of the excretions was increased. How much of the absorption, which must have been effected to replace the amount of excreted fluid, is to be attributed to the baths, and how much to the enemata, it is not easy to say; but it is important to remark that "the thirst, which was troublesome during the first days of the patient's abstinence, was abated, and, as he

* We have a remarkable exception to this general statement, however, in the case of Frogs and other Batrachia, which are characterized by the softness of their skins and the thinness of their epidermic covering; for cutaneous absorption seems in them to be no less active than their cutaneous exhalation and respiration are well known to be. Thus Frogs, which habitually live in a moist atmosphere, seldom or never drink; yet when they have lost fluid by exposure to hot dry air, they will regain their weight by being left for a time upon moist sand; and the bladder, which serves as a reservoir of water for cutaneous exhalation, though previously emptied, will be refilled.

† See a collection of such cases in Dr. Madden's "Experimental Enquiry into the Physiology of Cutaneous Absorption," p. 47.

declared, removed by the tepid bath, in which he had the most grateful sensations." "It cannot be doubted," Dr. Currie observes, "that the discharge by stool and perspiration exceeded the weight of the clysters;" and the loss by the urinary excretion, which increased from 24 oz. to 36 oz. under this system, is only to be accounted for by the cutaneous absorption.*—Dr. S. Smith mentions that a man, who had lost nearly 3 lbs. by perspiration, during an hour and a quarter's labour in a very hot atmosphere, regained 8 oz. by immersion in a warm bath at 95°, for half an hour.†—The experiments of Dr. Madden‡ on his own person show that a positive increase usually takes place in the weight of the body, during immersion in the warm bath, even though there is at the same time a continual loss of weight by pulmonary exhalation, and by transudation from the skin.§ This increase was, in some instances, as much as 5 drachms in half an hour; whilst the loss of weight during the previous half hour had been $6\frac{1}{2}$ drachms: so that, if the same rate of loss were continued in the bath, the real gain by absorption must have been nearly an ounce and a half. Why this gain was much less than in the cases just alluded to, is at once accounted-for by the fact, that there was no deficiency, in the latter case, of the fluids naturally present in the body.

469. There are certain phenomena, which, if accurately recorded, cannot be accounted-for in any other way, than by admitting that, under particular circumstances, a considerable amount of water may be absorbed from the *vapour* of the atmosphere. The following are among the most satisfactory and circumstantial observations that have been adduced in support of this position. Lining observed that his body on one occasion increased in weight during two hours to the amount of $8\frac{1}{2}$ oz., allowance being made for the amount of fluid ingested during that time, and for the quantity passed-off by the urine and by cutaneous transpiration.|| Dr. Jurin affirms that he ascertained an increase of 18 oz. to have taken place during a night passed in a cool room after a day's exercise and abstinence.¶ It is stated by Dr. Watson,** that a lad at Newmarket, having been almost starved, in order that he might be reduced to a proper weight for riding a match, was weighed at 9 A.M., and again at 10 A.M.; and he was found to have gained nearly 30 oz. in weight in the course of this hour, though he had only drunk half a glass of wine in the interim. A parallel instance was related to the Author by the late Sir G. Hill, then Governor of St. Vincent: a jockey had been for some time in training for a race, in which that gentleman was much interested, and had been reduced to the proper weight; on the morning of the trial, being much oppressed with thirst, he took one cup of tea; and shortly afterwards his weight was found to have increased 6 lbs., so that he was incapacitated for riding.—Nearly the whole of the increase in the former case, and at least three-fourths of it in the latter, must be attributed to absorption from the vapour of the atmo-

* "Medical Reports," vol. i. pp. 308–326. † "Philosophy of Health," vol. ii. p. 396.

‡ Op. cit., pp. 59–63.

§ That part of the function of cutaneous transpiration, which consists in simple exhalation, is of course completely checked by such immersion; but that which is the result of an actual secreting process in the cutaneous glands (CHAP. XII. Sect. 4) is increased by heat, even though this be accompanied with moisture.

|| "Philosophical Transactions," 1743, p. 496.

¶ Klapp, "Inaug. Dissert.," p. 30, cited by Dr. Madden.

** "Chemical Essays," vol. iii. p. 100.

sphere; probably, however, rather through the lungs than through the skin. If the possibility of such absorption be admitted, we are probably to attribute to it the chief part of the excess of watery fluid which cannot be otherwise accounted-for, in the following instances.—Dr. Dill* relates the case of a diabetic patient, who for five weeks passed 24 lbs. of urine every twenty-four hours; his ingesta during the same period amounted to 22 lbs. At the commencement of the disease he weighed 145 lbs.; and when he died, 27 lbs. of loss had been sustained. The daily excess of the excretions over the fluid ingesta could not have been less than 4 lbs.; making 140 lbs. for the thirty-five days during which the complaint lasted. If from this we deduct the amount of diminution which the weight of the body sustained during the time, we shall still have 113 lbs. to be accounted for, which can only have entered the body from the atmosphere.—A case of ovarian dropsy has been recorded by Mr. Ford,† in which it was observed that the patient, during eighteen days, drank 692 oz. or 43 pints of fluid, and that she discharged by urine and by paracentesis 1298 oz. or 91 pints, which leaves a balance of 606 oz. or 38 pints, to be similarly accounted for.‡

470. Not only water, but substances dissolved in it, may be thus introduced. It has been found that, after bathing in infusions of madder, rhubarb, and turmeric, the urine was tinged with these substances; and that a garlic plaster affected the breath, when every care was taken, by breathing through a tube connected with the exterior of the apartment, that the odour should not be received into the lungs.§ Gallic acid has been found in the urine, after the external application of a decoction of a bark containing it; and the soothing influence, in cases of neuralgic pain, of the external application of cherry-laurel water, is well known. Many saline substances are absorbed by the skin, when applied to it in solution; and it is interesting to remark, that, contrary to what happens in regard to the absorption of these from the alimentary canal, they are for the most part more readily discoverable in the Absorbents than in the Veins. This is probably due to the fact, that the imbibition of them takes place entirely according to physical laws; in conformity with which they pass most readily into the vessels which present the thinnest walls and the largest surface. In the intestines, the vascular plexus on each villus is far more extensive than the ramifying lacteal which originates in it; and as the walls of the veins are thin, there is considerable facility for the entrance of saline and other substances into the general current of the circulation: but in the skin, the lymphatics are distributed much more minutely and extensively than the veins; and soluble matters, therefore, enter them in preference to the veins. The absorbent power of the lymphatics of the skin is well shown by the following experiments. A bandage having been tied by Schreger round the hind-leg of a puppy, the limb was kept for twenty-four hours in tepid milk; at the expiration of this period, the lymphatics were found full of milk, whilst the veins con-

* "Trans. of Med.-Chirurg. Soc. of Edinb.," vol. ii.

† "Medical Communications," vol. ii. p. 130.

‡ In this case, however, as in others of a similar kind, something is to be allowed for the quantity of water contained in the solid food ingested; but this may be fairly considered not to exceed the quantity lost by pulmonary and cutaneous exhalation, and discharged in the fæcal evacuations.

§ Prof. Dunglison's "Human Physiology," 7th edit. vol. i. p. 688.

tained none. In repeating this experiment upon a young man, no milk could be detected in the blood drawn from a vein. It has been shown by Müller that, when the posterior extremities of a frog were kept for two hours in a solution of prussiate of potass, the salt had freely penetrated the lymphatics, but had not entered the veins.—It does not follow, however, from these and similar experiments, that in all tissues the lymphatics absorb more readily than the veins; for as the capillary blood-vessels in the lungs are much more freely exposed to the surface of the air-cells, than are the lymphatics, we should, on the principles just now stated, expect the former to absorb more readily. This appears from experiment to be the fact; for, when a solution of prussiate of potass was injected by Mayer into the lungs, the salt could be detected in the serum of the blood much sooner than in the lymph, and in the blood of the left cavities of the heart, before it had reached that of the right.

471. Our inferences with regard to the ordinary functions of the Lymphatic system, however, must be rather drawn from the nature of the fluid which it contains, and from the uses subsequently made of it, than from such experiments as the preceding. We shall presently see, that there is a close correspondence in composition between the Chyle of the Lacteals, and the Lymph of the Lymphatics; the chief difference being the presence of a considerable quantity of fatty matter in the former, and of a larger proportion of the assimilable substances (albumen and fibrin) which are equally characteristic of both (§ 474). This evident conformity in the nature of the fluid which these two sets of vessels transmit, joined to the fact that the fluid Lymph, like the Chyle, is conveyed into the general current of the circulation, just before the blood is again transmitted to the system at large, almost inevitably leads to the inference, that the lymph is, like the chyle, a *nutritious* fluid, and is not of an excrementitious character, as maintained by Hunter and his followers.* On the other hand, the close resemblance between the contents of the Lymphatics, and diluted Liquor Sanguinis, seems to indicate that the former are partly derived from the fluid portion of the blood, which has transuded through the walls of the capillary vessels; and we shall presently see reason to believe, that this transudation is partly for

* Since the time of Hunter, who first brought prominently forwards the doctrine alluded to, it has been commonly supposed (in this country at least) that the function of the Lymphatics is to remove, by interstitial absorption, the *effete* matter, which is destined to be carried out of the system; and any undue activity in this process (such as exists in ulceration), and any deficiency in its energy (such as gives rise to dropsical effusions, and other collections of the same kind), have been attributed to excess or diminution in the normal operation of the Absorbent system. All that we at present know, however, of the process of Nutrition, tends to the belief that the *effete* matters are carried off by the Venous system; for not only do we find no trace in the Lymph of any of those substances which are destined for elimination as excrementitious, but the Lymphatic vessels are either absent altogether, or exist in but very small numbers, in the Nervo-Muscular apparatus, which undergoes more constant interstitial change, and produces more effete matter by its disintegration, than does any other part of the organism. It may be safely affirmed that there is not a single fact to support what is known as the Hunterian doctrine; which could never have gained currency but for the authority of its great teacher,—its *originator*, perhaps, having been rather Hewson than Hunter. In the first edition of this work, the Author advanced the views stated above in the belief that they were original; he has since learned, however, that a similar doctrine had been put forth by Dr. Moultrie of South Carolina in the "Amer. Journ. of Med. Sci.," 1827; and by Dr. Dunglison in the first Edition of his "Human Physiology," 1832.

the purpose of subjecting the crude materials, which may have been taken up direct into the blood-vessels, to an elaborating or preparatory agency, such as it seems to be the especial object of the Lacteal system to exert upon the nutritive substances which it serves to introduce into the circulation.—But it seems not impossible, that there may be another source for the contents of the Lymphatics. We have already had to allude, on several occasions, to the disintegration which is continually taking place within the living body; whether as a result of the limited duration of the life of its component parts, or as a consequence of the decomposing action of Oxygen. Now the *death* of the tissues by no means involves their immediate and complete destruction; and there seems no more reason, why an animal should not derive support from its own dead parts, than from the dead body of another individual. Whilst, therefore, the matter, which has undergone too complete a disintegration to be again employed as nutrient material, is carried off by the excreting processes, that portion which is capable of being again assimilated, may be taken up by the Lymphatic system. If this be the case, we may say, with Dr. Prout, that "a sort of digestion is carried on in all parts of the body."—It may be stated, then, as a general proposition, that the function of the Absorbent System is to take up, and to convey into the Circulating apparatus, such substances as are capable of appropriation to the *nutritive* process; whether these substances be directly furnished by the external world, or be derived from the disintegration of the organism itself. We have seen that, in the Lacteals, the selecting power is such, that these vessels are not disposed to convey into the system any substances but such as are destined for this purpose; and that extraneous matters are absorbed in preference by the mesenteric Blood-vessels. The case is different, however, with regard to the Lymphatics; for there is reason to believe, that they are more disposed than the veins to the absorption of other soluble matters, especially when these are brought into relation with the Skin, through which the lymphatic vessels are very profusely distributed.

### 3.—*Of the Elaboration of the Nutrient Materials.—Sanguification.*

472. The alimentary substances, taken up by the Blood-vessels and Absorbents, seem very far from being capable of immediate application to the nutrition of the body; for we find that they are not conveyed by any means directly into the circulating current, but that those which enter the Gastro-intestinal veins are submitted to the operation of the Liver; whilst those which are received into the Lacteals are subjected to a kind of glandular action within their own system; the newly-absorbed materials in both cases undergoing considerable changes, which tend to assimilate them to the components of the Blood.—It will be recollected that all the veins which return the blood from the capillaries of the gastro-intestinal canal, converge into the portal trunk, which distributes this blood, charged with the newly-absorbed materials, through the capillary system of the Liver. The agency of this gland was formerly supposed to be limited to the elimination, from the blood subjected to its influence, of the materials of the biliary secretion; but there is now evidence that the blood itself is changed by its means, in a manner which indicates an

*assimilating* as well as a *depurating* action. The blood which comes to the Liver from the alimentary canal, is charged with albuminous matter in a state different from that of the albumen of perfect blood (§ 167); and the assimilation of this would appear, from the observations and experiments of M. Cl. Bernard formerly referred to (§ 169), to be one of the most important functions of the liver. So, again, the saccharine matters which are brought to the Liver in the condition of grape-sugar or of cane-sugar, are converted by its agency into liver-sugar; a form of the saccharine principle, of whose presence the blood is much more tolerant than it is of any other (§ 45). From the saccharine compounds brought to the Liver, moreover, it appears that Fatty matter can be generated (§ 40); but as the introduction of this substance into the blood-vessels ordinarily takes place through a different channel, the action of the liver would not appear to be essential to its assimilation, and it has been found by M. Bernard that oil may be injected into the general circulation without exciting any violent effort at its elimination. — There is evidence that the Liver may be subservient even to the *vital* transformation of the components of the blood. For it has been observed by Prof. E. H. Weber, that, during the last three days of incubation of the chick, the liver is made bright-yellow by the absorption of the yolk, which fills and clogs all the minute branches of the portal veins; and that in time the materials of the yolk disappear, part being developed into blood-corpuscles and other constituents of blood, which enters the circulation, and the rest forming bile, and being discharged into the intestine.* And it is asserted by M. Bernard that the quantity of fibrin is relatively so much greater in the blood of the hepatic vein, than in the portal blood, that the metamorphosis of albumen into fibrin must be admitted to be one of the functions of the liver;†—upon this point, however, he is by no means in accordance with other observers.

473. The whole Absorbent system may be looked upon as constituting one great *Assimilating Gland*, dispersed through the body at large; for it does not differ in any essential particular from what the Kidney or the Testis would be, if it were simply unravelled, and its convoluted tubuli spread through the entire system, yet still all discharging their secreted products by a common outlet. In the cold-blooded Vertebrata, we find the extent of its tubuli enormously increased by the plexuses which they form around the veins; so that the Absorbent system *appears* to attain a relatively greater development in them, than it does in the higher classes. But the difference really lies in the greater diffusion, in the former, of the elements which are more concentrated in the latter. In Birds, the plexuses are smaller, and we meet in them with the 'glands' or 'ganglia,' of which the Absorbent system of Reptiles and Fishes is completely destitute. And in Mammals, the plexuses almost entirely disappear, and their place is occupied by the 'glands' which are found in the course both of the lacteal and lymphatic Absorbents. These bodies, wherever they occur, have the same essential structure; and may be described as consisting of convoluted knots of absorbent vessels, their

* "Henlé and Pfeufer's Zeitschrift," 1846.

† See on the whole of this subject, M. Cl. Bernard's Lectures on the 'Functions of the Liver,' delivered before the Collège de France, and published in "L'Union Médicale" for 1850.

simple cylindrical canals, however, being usually dilated into larger cavities or 'cells' that freely communicate with each other; and capillary vessels being minutely distributed among them. These blood-vessels have no direct communication with the interior of the absorbents and the cavities of the glandulæ, being separated from them by the membranous walls of both sets of tubes; but there can be no doubt, that transudation readily takes place from one set of canals to the other. The epithelium, which lines the absorbent vessel, undergoes a marked change where the vessel enters the gland; and, according to Prof. Goodsir,* becomes more like that of the proper glandular follicles in its character. Instead of being flat and scale-like, and forming a single layer in close apposition with the

Fig. 101.

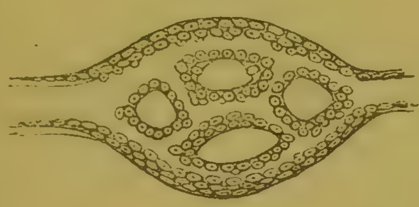
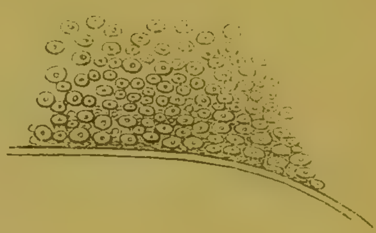


Diagram of a *Lymphatic gland*, showing the intra-glandular network, and the transition from the scale-like epithelia of the extra-glandular lymphatics, to the nucleated cells of the intra-glandular.

Fig. 102.



Portion of *intra-glandular Lymphatic* showing along the lower edge the thickness of the germinal membrane, and upon it, the thick layer of glandular epithelial cells.

basement-membrane, as it does in the absorbents previous to their entrance into the gland and after their emergence from it (Fig. 101), we find it composed of numerous layers of spherical nucleated cells, (Fig. 102), of which the superficial ones are easily detached, and appear to be identical with the cells found floating in the Chyle (§ 475).

474. *Composition and properties of the Chyle and Lymph.*—The chief chemical difference between these fluids consists in the much smaller proportion of solid matter in the Lymph, and in the almost entire absence of fat, which is an important constituent of the Chyle. This is well shown in the following comparative analyses, performed by Dr. G. O. Rees,† of the fluids obtained from the lacteal and lymphatic vessels of a donkey, previously to their entrance into the thoracic duct; the animal having had a full meal seven hours before its death.

| | Chyle. | Lymph. |
|---|---|---|
| Water | 90·237 | 96·536 |
| Albuminous matter (coagulable by heat) | 3·516 | 1·200 |
| Fibrinous matter (spontaneously coagulable) | 0·370 | 0·120 |
| Animal extractive matter, soluble in water and alcohol | 0·332 | 0·240 |
| Animal extractive matter, soluble in water only | 1·233 | 1·319 |
| Fatty matter | 3·601 | a trace. |
| Salts;—Alkaline chloride, sulphate and carbonate, with traces of alkaline phosphate, oxide of iron | 0·711 | 0·585 |
| | 100·000 | 100·000 |

* "Anatomical and Pathological Observations," p. 46.—It has recently been denied by Prof. Bennett, however, that these cells are *epithelial*, or given off from a basement-membrane such as that described by Prof. Goodsir (§ 119); their formation being, in Prof. Bennett's opinion, from nuclei developed freely in the midst of the fluid. (See "Edinb. Monthly Journ." March, 1852, p. 284).

† "Medical Gazette," Jan. 1, 1841.

The Lymph obtained from the neck of a horse has been analysed by Nasse, with nearly the same result. He found it to contain 95 per cent of water; and the 5 per cent of solid matter was chiefly composed of albumen and fibrin, with watery extractive, scarcely a trace of fat being discoverable. The proportions of saline matter were found to be remarkably coincident with those which exist in the serum of the blood; as might be expected from the fact, that the fluid portion of the lymph must have its origin in that which has transuded through the blood-vessels: the absolute quantity, however, is rather less. A similar analysis of the Chyle of a cat by Nasse, has given results very closely correspondent with that of Dr. Rees; for the proportion of water was 90·5 per cent; and of the 9·5 parts of solid matter, the albumen, fibrin, and extractive amounted to more than 5, and the fat to more than 3 parts.*—Dr. Rees has also analysed the fluid of the Thoracic duct of Man;† and found it to consist of 90·48 per cent of water, 7·08 parts of albumen and fibrine, 1·08 parts of aqueous and alcoholic extractive, and 0·92 of fatty matter, with 0·44 per cent of salines. Thus the composition of this fluid would seem to resemble that of the Lymph, rather than that of the Chyle; the proportion of the fatty to that of the albuminous matter being very small. This, however, might have been very probably due to the circumstance, that the subject from which the fluid was obtained (an executed criminal) had eaten but little for some hours before his death.

475. The characters of the *Chyle* drawn from the larger absorbent trunks, near their entrance into the receptaculum chyli, are very different from those of the fluid as first absorbed into the Lacteals; for during its passage through these vessels, and their ganglia or glands, it undergoes important alterations, which gradually assimilate it to Blood. The chyle drawn from the lacteals that traverse the intestinal walls, contains Albumen in a state of complete solution; but it is generally destitute of the power of coagulation, no Fibrine being present in it. The Salts, also, are completely dissolved; but the Oily matter presents itself, in the form of globules of variable size.‡ It is generally supposed, that the milky colour of the chyle is owing to these; but Mr. Gulliver has pointed out§ that it is really due to an immense multitude of far more minute particles, which he describes as forming the *molecular base* of the chyle. These molecules are most abundant in rich, milky, opaque chyle; and in poorer chyle, which is semi-transparent or opaline, the particles float thinly or separately in the transparent fluid, and often exhibit the vivid motions common to the most minute molecules of various substances. Such is their minuteness, that, even with the best instruments, it is impossible to form an exact appreciation either of their form or their dimensions. They seem, however, to be generally spherical; and their diameter may be estimated at between 1-36,000th and 1-24,000th of an inch. Their chemical nature is as yet uncertain: they are remarkable for their unchangeableness, when

* Wagner's "Handwörterbuch," Art. 'Chylus.'

† "Philosophical Transactions," 1842.

‡ These oily globules are more abundant in the Chyle of Man and of the Carnivora, than in that of the Herbivora; their diameter has been observed to vary from 1-25,000th to 1-2000th of an inch.

§ "Dublin Medical Press," Jan. 1, 1840, and "Gerber's General Anatomy," Appendix, p. 88.

ubjected to the action of numerous re-agents which quickly affect the roper Chyle-corpuscles; and they are readily soluble in ether, the addi- ion of which causes the whole molecular base instantly to disappear, not particle of it remaining; whence it may be inferred that they consist of ily or fatty matter. That they do not ordinarily tend to coalesce, is pro- ably due to the coating of albumen which they obtain through their iffusion in an albuminous fluid (§ 42, note); if, however, this be dis- olved by acetic acid, or even by the addition of water, many of the nolecules are lost sight of, and oil-drops appear in their place. The ilky colour, which the serum of blood sometimes exhibits in healthy ubjects, is due to an admixture of this molecular base with the circulating uid (§ 41).

476. During the passage of the Chyle through the absorbents on the itestinal edge of the Mesentery, towards the Mesenteric Glands, its cha- acter changes in several important particulars. The presence of Fibrin egins to manifest itself, by the slight coagulability of the fluid when vithdrawn from the vessels; and while this ingredient increases, the lbumen and the Oil-globules gradually diminish in amount. The Chyle rawn from the neighbourhood of the mesenteric glands exhibits the orpuscles regarded as characteristic of that fluid; these are peculiarly bundant in the fluid drawn from the glands themselves; and they are onstantly found in it, through its whole subsequent course. The Chyle- orpuscles are much larger than the molecules just described, and an xamination of their character presents no difficulty. Their diameter aries from 1-7110th to 1-2600th of an inch: the average being about -4600th. They are usually minutely granulated on the surface, seldom ex- ibiting distinct nuclei, even when treated with acetic acid; but sometimes ree or four central particles may be distinguished within them. They orrespond in all essential particulars with the Colourless Corpuscles of e Blood (§ 145), but appear to be in an earlier stage of formation.— uring the passage of the Chyle through the mesenteric glands, a further crease in the proportion of Fibrin takes place; and the resemblance of e fluid to Blood becomes more apparent. The Chyle drawn from the essels intermediate between these and the central duct, possesses a pale ddish-yellow colour; and, when allowed to stand for a time, undergoes regular coagulation, separating into *clot* and *serum*. The former is a onsistent gelatinous mass, which, when examined with the microscope, found to include the Chyle-corpuscles, each of them being surrounded y a delicate film of oil: the Fibrin of which it is principally composed, ffers remarkably from that of the blood, in its inferior tendency to utrefaction; whence it may be inferred that it has not yet undergone s complete vitalisation. The serum contains the Albumen and Salts in lution, and a proportion of the Chyle-corpuscles suspended in it. It is urious, however, that considerable differences in the perfection of the agulation, and in its duration, should present themselves in different periments. Sometimes the chyle sets into a jelly-like mass, which, ithout any separation into coagulum and serum, liquefies again at the d of half an hour, and remains in this state. This change takes place the true coagulum also, if it be kept moist for a sufficient length of ne.—The Chyle from the Receptaculum and Thoracic Duct coagulates uickly, often almost instantaneously; and few or none of the corpuscles

remain in the serum. The fluid drawn from the Thoracic Duct, and from the Absorbent vessels which empty their contents into it, is frequently observed to present a decided red tinge, which increases on exposure to the air. This tinge appears to be due to the presence of Red blood-corpuscles in an early stage of formation (§ 150). The ordinary corpuscles, moreover, have a more distinctly *cellular* character, than have those of the chyle and lymph; and they are of larger size, their diameter usually ranging from about 1-2600th to 1-2900th of an inch. In these particulars, they correspond with the Colourless corpuscles of the Blood; as also in the change they exhibit on the action of acetic acid, which brings into view three or four large central particles.—The following table, slightly modified from that of Gerber,* presents, in a concise form, a view of the relative proportions of the three chief ingredients in the Chyle, in different parts of the absorbent system, and thus gives an idea of its advance in the process of assimilation.

| | |
|---|---|
| In the afferent or peripheral Lacteals (from the Intestines to the Mesenteric glands). | Fat, in maximum quantity (numerous fat or oil-globules).<br>Albumen in medium quantity.<br>Few or no Chyle-corpuscles.<br>Fibrin almost entirely wanting. |
| In the efferent or central Lacteals (from the Mesenteric glands to the Thoracic Duct.) | Fat, in medium quantity (fewer oil globules).<br>Albumen in maximum quantity.<br>Chyle-corpuscles very numerous, but imperfectly developed.<br>Fibrin in medium quantity. |
| In the Thoracic Duct. | Fat, in minimum quantity (fewer or no oil globules).<br>Albumen in medium quantity.<br>Chyle-corpuscles numerous, and more distinctly cellular.<br>Fibrin in maximum quantity. |

477. The aspect of the *Lymph* greatly differs from that of the Chyle, the former being nearly transparent, while the latter is opaque or opalescent; and this difference is readily accounted for, when the assistance of the microscope is sought, by the entire absence from the Lymph of that 'molecular base' which is so abundant in the Chyle. A considerable number of corpuscles are generally present in it; and these, like the chyle-corpuscles, correspond in all respects with the colourless corpuscles of the Blood (§ 145). Their amount, however, is extremely variable; as is also that of the oil-globules, which sometimes occur, whilst in other instances none can be discovered. Lymph coagulates like chyle; a colourless clot being formed, which incloses the greater part of the corpuscles.

478. The fluid drawn from the Thoracic Duct, consisting as it does of an admixture of Chyle and Lymph, will probably vary in its character and composition, according to the predominance of the former, or of the latter, of these constituents.—From some observations made by Biddert on the quantity of fluid discharged from the thoracic ducts of dogs and cats immediately after death, it is inferred by him that the total amount of mingled lymph and chyle which is daily poured into the circulating current, is equal in bulk to at least two-thirds the entire mass of the blood; though it furnishes, bulk for bulk, not more than from one-fourth to one-third the quantity of solid matter which the blood contains. It is difficult to suppose, however, that so large a

* "General Anatomy," edited by Gulliver, p. 94. † "Müller's Archiv.," 1845.

antity really enters the circulating current through this channel, in dition to that which is taken-up by the veins; and it is obvious that ere are many circumstances which prevent the results of such ob-vations from being fairly assumed as furnishing an average for the tire day.

479. The movement of the fluids taken-up by the Absorbent vessels ms to depend upon a combination of different agencies. The lower rtebrata are provided with 'lymphatic hearts,' or pulsatile cavities, by ich important assistance is given in the onward flow; but no such aid afforded in Man or in the Mammalia; yet it is obvious that a consi-rable *vis a tergo* must exist, since, if the thoracic duct be tied, it is edily distended below the ligature, even to bursting. The Absorbent ssels, like the veins, have a fibrous coat, into which the muscular fibre-lls enter largely, and which is therefore contractile; and it has been und by Prof. Kölliker, that when the wire of an electro-magnetic paratus was applied to some well-filled lymphatics on the skin of a boy's ot, soon after the removal of his leg by amputation, the stimulus occa-ned a diminution in their diameter by at least one-half, and this not ddenly, but in the course of between half a minute and a minute.* The ne excellent observer has observed that the lymphatic vessels in the tail a Tadpole empty themselves by contraction after death, and then dilate ain to their former size, just as the smaller arteries do under the like cumstances;† and this fact is in accordance with the emptiness of the sorbent system, which usually presents itself in Man some little time er death. Hence it seems probable that regular propulsion of the id during life may be effected by alternate contractions and dilatations successive portions of the vessels, slowly repeated at intervals.‡—There e, however, certain auxiliary forces. For, in the first place, a part of movement may be attributed to the *vis a tergo*, which is produced by continual introduction of fresh fluid into the rootlets, so to speak, the vascular tree; and this more especially in the case of the lacteals, ce the muscularity of the villi seems to enable them to act as so many nute force-pumps, whereby the fluid which they have imbibed may be pelled onwards (§ 460). It may be thought that, from the extreme tensibility of the walls of the absorbents, this force would be rather pended in dilating them, than in pushing-on the current of liquid ich they contain; but it must be borne in mind that they are for the st part closely surrounded with tissues which exert a certain degree of essure upon them, and that this is much greater during life than after ath. Further, in all the moveable parts of the body, assistance is ubtless afforded (as it is to the circulation in the Veins, CHAP. IX. ct. 4) by the occasional pressure exercised upon the Absorbents by the rounding tissues; for while this pressure is operating, it will tend to

* "Kölliker and Siebold's Zeitschrift," 1849.

† "Annales des Sciences Naturelles," 1840, Zool., tom. vi. p. 99.

‡ A regular rhythmical movement of the *veins* of the Bat's wing, obviously dependent n their independent contractility, has lately been observed by Mr. Wharton Jones Proceedings of the Royal Society," Feb. 5, 1852). The existence of such a movement in Veins of a part, as an auxiliary propulsive force, obviously strengthens the probability of occurrence in the Lymphatics, as the principal propelling power, where no central impulsive in exists; just as a like movement is seen in the blood-vessels of such of the lower ertebrata as have no heart.

empty them of their contents, which are only permitted by their valves to pass in one direction; and when the pressure is relaxed, they will be refilled from behind.

480. It seems obvious, from what has been stated, that we are to regard the entire Absorbent system as a great *blood-making* gland (§ 473), designed to exert a certain power of conversion or vitalization over the matters which enter it, either from the alimentary canal or from the body in general.—In the case of the Lacteal portion of the system, there seems to be a strong indication that one part of the converting process consists in the intimate admixture which the albuminous constituent of the chyle undergoes with its fatty constituent, owing to the subdivision of the latter, and its diffusion through an albuminous fluid. And the effects of this admixture are peculiarly shown by the tenacity with which fat is incorporated with albumen and fibrin (§ 20, 25), so that it is difficult to separate them; this incorporation, it seems probable, having a peculiar reference to the very first process of cytogenesis, in which molecules of fatty matter seem always to be present in close collocation with albuminous particles (§ 42). As already pointed out, the 'plasticity' of the different albuminous compounds holds such a direct relation to the quantity of fat they contain (within certain limits), that we can scarcely help looking at this incorporation as one of the most important parts of the assimilating process. And thus it seems to be, that the presence of fatty matters in the food is essential to healthy nutrition (§ 404, III.); for no production of fat by the agency of the liver can bring the raw albumen into the same intimate relationship with the minutely-divided fatty molecules. What other changes the fluid of the lacteals may undergo, in addition to the production of fibrin and of corpuscles which has been already noticed, and what is the special purpose of the elaboration to which the fluid of the Lymphatics is subjected, cannot as yet be distinctly stated. Probably, however, the changes in question are less of a chemical than of a vital nature, and are such as serve to prepare the fluid for maintaining the vital activity of the several parts of the organism to which it is to be distributed.

481. *Ductless Glands.*—There is reason to believe that a similar office is performed by certain bodies connected with the Circulating system, which possess the essential elements of the Glandular structure, without any efferent ducts; these must restore to the circulating current any substances which they may withdraw from it; and there seems adequate ground, therefore, for the conclusion, that their action, whatever it may be, is subsidiary to the completion of the process of Sanguification,—being exercised, perhaps, upon that portion of the nutrient materials more especially, which did not traverse the Absorbent system when first introduced, but which was directly taken-up by the blood-vessels. The organs in question, which have received the distinctive appellation of *Vascular* or *Ductless* Glands, are the Spleen, the Thymus, Thyroid, and Supra-renal bodies. Of these, the Spleen deserves especial notice, on account of its size and obvious functional importance in the adult; the others appear to minister more particularly to the requirements of the system at the earlier periods of life.

482. The minute structure of the *Spleen* has recently been made the subject of careful research by many excellent Microscopic observers; and

ore especially Prof. Kölliker* and by Dr. Sanders†. The following a summary of the most important points which they may be considered have determined.

I. The *fibrous coat* in Man is composed of white fibrous tissue, with intermixture of yellow or elastic fibres; in many of the lower imals, however, it contains non-striated muscular fibres composed of siform fibre-cells.

II. The *trabecular tissue* consists of fibrous bands, and threads which ise from the inner surface of the fibrous envelope, and form a network at extends through the entire organ, becoming connected also with e fibrous sheaths of the vessels which penetrate it. These bands are rtly muscular in the animals which have muscular fibres in the external velope of the spleen; but elsewhere they are simply fibrous. The spaces t by their intersection, which are by no means regular either as to form size, are occupied by the splenic corpuscles and splenic parenchyma. the trabeculæ of the human spleen, Prof. K. has discovered some culiar fusiform cells with *round* nuclei, which are probably to be conlered as contractile cells not developed into their properly characristic form (§ 305).

III. The peculiar *Splenic Corpuscles*, sometimes termed the 'Malpighian rpuscles' of the Spleen, are whitish spherical bodies, which are imbedd in the splenic parenchyma, but are connected with the smaller arteries short peduncles, like grapes with their fruit-stalks, or are sessile upon eir sheaths. Owing to the rapid changes which they undergo after ath, and the influence of previous disease and abstinence, they are selm seen in the Human subject, but are best seen in the perfectly fresh leens of the Ruminantia; there is no doubt, however, of their invariable esence in the healthy human subject, although this has been denied by ny anatomists. The size of these corpuscles, when fully developed, ries from about 1-3d to 1-6th of a line; smaller bodies, however, are t with, which appear to be Malpighian corpuscles in an earlier stage of olution. Each of them consists of a delicate fibrous envelope, derived m the sheath of the artery to which it is attached, and frequently surnded by capillaries of extreme minuteness. It contains, as its connt and essential elements, nucleated cells of from 1-6000th to 1-4000th an inch in diameter, pale and faintly granular, together with free nuclei e proportion of which to that of the fully-formed cells is extremely riable), and a few of larger size, and more distinctly granular before the lition of reagents, from 1-3500th to 1-3000th of an inch in diameter. sides these and other varieties of cells contained in the Malpighian corscles, Dr. Sanders describes a peculiar set of spherical cells, of a bright den colour, usually from 1-1200th to 1-1500th of an inch in size, each ring a single nucleus; which cells form a regular layer beneath the sule. Among these are seen other cells of 1-1000th of an inch or re in diameter, containing two or three nuclei; and yellow globules of diameters from 1-4000th to 1-12000th of an inch, which are probably ner free nuclei or young cells of this class. Between the corpuscular itents of the Malpighian corpuscles, there intervenes a homogeneous

"Cyclopædia of Anatomy and Physiology," Art. 'Spleen;' and "Mikroskopische itomie," band ii. §§ 183–189.

"Annals of Anatomy and Physiology," No. 1.

or slightly granular plasma.—The remarkable discovery has recently been made by Dr. Sanders, that the interior of the Malpighian corpuscles is traversed (like that of the Peyerian vesicles, § 456), by arterial twigs of considerable size; which may be demonstrated by boiling the tissue in acidulated water, drying it, and then cutting thin sections.*—Many observers have affirmed that there is some special connection between the Malpighian corpuscles and the Lymphatics of the spleen; but it may be considered as quite determined by the concurrence of the most recent observations on this point, that no such communication exists.

IV. The true *Splenic Parenchyma* consists in great part of cells, which correspond in appearance with those of the Malpighian corpuscles, and which are, like them, imbedded in a nearly homogeneous plasma; but two other kinds of cells occur in it, which are seldom met with in the latter; and numerous free nuclei are also present. Of these two kinds of cells, one set is smaller, and the other larger, than the average of the parenchymatous cells; the former bear a strong resemblance to red blood-corpuscles, but are of a paler colour; the latter are partly pale cells, of 1-1700th of an inch in diameter, with one or two nuclei, or granule-cells of from 1-3000th to 1-2000th of an inch of a line, which may be described as "colourless granule-cells."—These elements of the pulp, like the contents of the Malpighian corpuscles, vary greatly in their proportions to each other; from which it may be concluded that they are in a state of continual development and degeneration. They do not lie collected in large heaps, but form small irregular groups of different sizes, which are clustered especially on the sheaths of the vessels, the trabecular partitions, and the membranes of the Malpighian corpuscles; they are not themselves included, however, in special envelopes.—Besides the usual corpuscles and granules of the parenchyma, it contains dispersed through it, in very inconstant amount, some remarkable coloured particles, varying from the size of small granules to that of blood-corpuscles, and often aggregated in masses of 1-1000th of an inch in diameter, having a distinct envelope which sometimes contains as many as twenty corpuscles. These are probably, as asserted by Kölliker, blood-corpuscles in various stages of degeneration; but they are by no means peculiar to the spleen, for they present themselves in many other situations where extravasations of blood occasionally occur; and, as remarked by Dr. Sanders, "from all the circumstances connected with them, they would appear to be the product, not of organic processes, but of physical alteration in stagnant blood, and are only more abundant in the spleen, because more blood is retained after death in its pulp, than in the substance of other organs."

V. Of the *Splenic Arteries*, it is chiefly to be observed that their branches form no anastomoses, but that they subdivide and ramify like the branches of a tree, with the Malpighian corpuscles attached to them as fruit. Beyond their connection with these, however, they enter into the red spleen-substance; and here each twig subdivides into a tuft of arteries still more minute, which again subdivide into the true capillaries that constitute a close and beautiful network in the splenic pulp.—Of the *Veins*, it is positively affirmed by Prof. Kölliker, that the idea long entertained as to their dilatation into cavernous spaces or sinuses is incorrect,

* See "Edinburgh Monthly Journal," March, 1852, p. 286.

so far as the Human spleen is concerned; and that there is nothing peculiar in their distribution, save in their mode of ramification, which closely resembles that of the arteries, and in the absence of valves. In the spleen of the Ox, however, and of other Ruminants, a true *cavernous* structure does exist.

VI. The *Lymphatics* of the Spleen are few and inconsiderable in Man; being less numerous than in other glandular organs, such as the liver and kidneys. In some of the lower animals they are more abundant; but even here they are mostly superficial, and scarcely penetrate to the interior of the organ.

VII. The *Nerves* of the Spleen are apparently very large in some animals, especially in the Ruminants; but the great size of their trunks and branches is chiefly due to the large proportion of ordinary fibrous tissue which enters them; the number of real nerve-fibres being extremely small.

483. The history of the *development* of the Spleen, which has been recently studied with great care by Mr. H. Gray,* presents facts of great interest, as aiding in the determination of the functional character of this organ, and of the nature of its component parts.—It arises in the Chick between the 4th and 5th days of incubation, in a fold of membrane which connects the intestinal canal to the spine (the 'intestinal lamina'), as a small whitish mass of blastema, perfectly distinct from both the stomach and the pancreas; from the former of which it has been said by Bischoff, and from the latter by Arnold, to take its origin. The external capsule and the trabecular tissue are developed between the 8th and 9th days; the former as a thin membrane composed of nucleated fibres, the latter consisting of similar fibres which intersect the organ at first sparingly, and afterwards in greater quantity. The blood-vessels of this organ are formed within itself, independently of those which are exterior to it; and blood-corpuscles are also observed to originate in the substance of its blastema, their formation continuing until its connection with the general vascular system is completed, at which period their development appears to cease.—The pulp-tissue at an early period of its formation, closely corresponds with that of the supra-renal and thyroid bodies in their earliest stages of evolution; consisting of nuclei, nucleated vesicles, and a fine granular plasma. When the splenic vessels are formed, many of these nuclei are surrounded by a quantity of fine dark granules, arranged in a circular form; and these increase up to the time when the splenic vein is formed, when nearly the whole mass is composed of nucleated vesicles, the nuclei of which gradually break up into a mass of granules which fill the cavities of the vesicles. The Malpighian vesicles are developed in the pulp, by the aggregation of nuclei into circular masses, around which a fine membrane soon appears, in a manner precisely similar to those of the supra-renal (§ 485) and thyroid bodies.

484. The *Supra-Renal* bodies in Man and most Mammalia, present, like the kidneys, a division into cortical and medullary substances; the former having a lighter hue than the latter.—The *cortical* substance is principally formed of closed vesicles, which are arranged in linear series (so as

* "Proceedings of the Royal Society," Jan. 15, 1852.

to present the appearance of radiating tubes), and which are united by ensheathing coats derived from processes of the fibrous envelope. According to Ecker,* who is confirmed on this point by Frey,† these vesicles always remain distinct; but Mr. Gray appears to think that there is sometimes an absolute coalescence between them (§ 485). The diameter of the vesicles varies from about 1-1500th to 1-800th of an inch; and some of them have a length of from 1-650th to 1-480th of an inch. The contents of these vesicles are (1) a finely-granular plasma rich in albumen, (2) nuclear corpuscles, usually from 1-3000th to 1-4000th of an inch in diameter, (3) cells of from 1-2000th to 1-1350th of an inch in diameter, whose membrane seems to be formed by a sort of precipitation of the granules upon the nuclei, and (4) fatty particles of various sizes, the proportion of which varies. Besides the fully-formed vesicles, the parenchyma also contains numerous isolated cells, which have been thought to be vesicles in an earlier stage of development, but which would appear, from the observations of Mr. Gray (§ 485) to be rather cells as yet unenclosed in vesicles.—The *Medullary* substance, when thin slices of it are examined, is found to be considerably more transparent than the cortical; this being due to the absence of fat-particles from its substance. It does not contain any glandular vesicles; but consists entirely of a basis of fibrous tissue, which is formed by processes that come off from the sheath of the cortical substance, and which contains numerous blood-vessels and nerves. The interspaces of this tissue, however, are occupied by a granular plasma, in which are nuclei and cells in various stages of development.—The cortical substance has a much larger supply of blood than the medullary; for each of the gland-vesicles is surrounded by a network of arterial capillaries with long meshes, derived from primitive branches of the supra-renal arteries; whilst other branches pass at once towards the medullary substance, and there break up into twigs, which return by devious paths into the cortical mass, there to end in a capillary network. This superiority in vascularity evidently has reference to the greater functional activity of the cortical substance. The supra-renal capsules are by no means copiously supplied with Lymphatics; indeed it is doubful whether these vessels penetrate their interior. The nerves of these organs (which are all derived from the plexuses of the Sympathetic system) are particularly numerous; no such supply being possessed by any similar organs.‡

485. The development of the Supra-Renal bodies also has been studied by Mr. Gray (loc. cit.). He states that they arise on the 7th day of incubation as two separate masses of blastema, situated between the upper end of the Wolffian bodies and the sides of the aorta, being totally independent (as concerns their development) of those bodies or of each other. At this period, their minute structure bears a close resemblance to that

* "Annales des Sciences Naturelles," Aug. 1847.

† "Cyclopædia of Anatomy and Physiology," Art. 'Supra-renal Capsules.'

‡ It is a curious observation, which has been recently made by M. Brown-Séquard, that injuries to the Spinal Cord in the dorsal region, occasion congestion and (after a time) hypertrophy of the supra-renal capsules ("Gazette Médicale," Fevr. 1, 1852). It is no objection to the idea that this change is dependent upon nervous agency, that no spinal nerves proceed to these organs; since we know that a large number of spinal fibres enter the parts of the Sympathetic system whence they receive their supply.

of the spleen, consisting of the same elements as that gland, excepting in the existence of more numerous dark granules, which give to the organ at a later period an opake and darkly granular texture. The gland-tissue of the organ, in the form of large vesicles, makes its appearance on the 8th day; and is evolved in the same manner as that of the spleen, namely, by an aggregation of nuclei into circular masses, around which a limitary membrane ultimately forms. These are at first uniformly grouped together, without any subdivision into cortical and medullary portions; but on the 14th day, the first trace of this subdivision becomes manifest, by the aggregation of the vesicles into masses which radiate from the circumference towards the centre of the gland; complete tubes being sometimes formed by the junction of the vesicles, as indicated by the hemispherical bulgings on their walls. At a later period, the organs increase in size, and attain their usual position; and a more complete subdivision into cortical and medullary portions is observed.—The earlier appearance of the vesicular structure of these bodies, as compared with that of the Malpighian bodies of the spleen, is a fact of much interest, when considered with reference to the period of greatest functional activity in the two organs respectively. For the Supra-Renal bodies attain a very large size in fœtal life, surpassing the Kidneys in dimension up to the tenth or twelfth week of Human embryonic development; though they afterwards diminish so much, relatively to the Kidneys, as to possess in the adult condition only 1-28th part of their bulk.

486. The elementary structure of the *Thymus* Gland may be best understood from the simple form it presents, when it is first capable of being distinguished in the embryo. It then consists of a single tube, closed at *both* ends, and filled with granular matter; and its subsequent development consists in the lateral growth of branching off-shoots from this central tubular axis. In its mature state, therefore, it consists of an assemblage of glandular follicles, which are surrounded by a plexus of blood-vessels; and these follicles all communicate with the central reservoir, from which, however, there is no outlet. The cavities of the follicles contain a fluid, in which a number of corpuscles are found, giving it a granular appearance. These corpuscles, the diameter of which varies from 1-5750th to 1-2550th of an inch, usually averaging between 1-4000th and 1-5000th, are for the most part in the condition of *nuclei;* but fully-developed cells are found among them, at the period when the function of this body seems most active. The chemical nature of its contents, at this period, closely resembles that of the ordinary protein-compounds.—The Vascular supply of this organ, during the period of its functional activity, is extremely abundant; and the capillary network into which the arterial branches subdivide, closely surrounds the exterior of the follicles, and is so exceedingly dense that its meshes are of less diameter than the vessels themselves. The Lymphatics are large, and communicate directly with the Vena Cava; but their immediate connection with the cavity of the Thymus body has not yet been demonstrated. It has been commonly stated, that the Thymus attains its greatest development, in relation to the rest of the body, during the latter part of fœtal life; and it has been considered as an organ peculiarly connected with the embryonic condition. But this is a mistake; for the greatest activity in the growth of this organ manifests itself, in the Human infant, soon after birth; and it is then, too,

that its functional energy seems the greatest. This rapid state of growth, however, soon subsides into one of less activity, which merely serves to keep up its proportion to the rest of the body; and its increase usually ceases altogether at the age of about two years. From that time, during a variable number of years, it remains stationary in point of size; but, if the individual be adequately nourished, it gradually assumes the character of a mass of fat, by the development of the corpuscles of its interior into fat-cells, which secrete adipose matter from the blood. This change in its function is most remarkable in hybernating Mammals; in which the development of the organ continues, even in an increasing ratio, until the animal reaches adult age, when it includes a large quantity of fatty matter. The same is the case, generally speaking, among Reptiles.*

487. The *Thyroid* body accords rather with the Supra-renal capsules, than with the Thymus, in its elementary structure; for it consists of a number of isolated vesicles, which do not communicate with any common reservoir. These vary in diameter, in the Human subject, from 1-2000th to 1-85th of an inch; and they contain an albuminoid plasma,† which is either faintly granular, or of a somewhat oily aspect, amidst which are seen a number of corpuscles, of an average diameter of 1-3000th of an inch, of which the greater part are in the condition of nuclei, whilst some have advanced to that of cells. These corpuscles seem rather to occupy the position of an epithelium within the vesicles, than to float freely in their contained fluid.—The vascular supply of the Thyroid body is extremely abundant; and, as in the preceding instances, the subdivisions of its arteries form a very minute capillary plexus upon the membrane of the vesicles. The Lymphatics have not been traced far into its substance. —The development of the Thyroid body has been shown by Mr. Gray (loc. cit.) to be closely accordant with that of the 'ductless glands' already described. This body originates in two separate masses of blastema, one at each side of the root of the neck, close to the separation of the carotid and subclavian vessels, and between the trachea and the branchial clefts, but quite independent, as far as regards their development, of either of those parts. Their minute structure at an early period closely corresponds with that of the spleen and supra-renal glands; and the formation of their vesicles takes place after precisely the same plan. This body, like the Supra-renal and Thymus, is of larger relative magnitude during intra-uterine existence and infancy, than in after-life.

488. That the Ductless Glands, of whose peculiar structure and relations we have thus taken a general survey, have some office of importance to perform in the preparation and maintenance of the Blood, cannot any longer be reasonably questioned; and the determination of this point may be fairly regarded as a considerable step in the investigation. It is obvious, from the very copious supply of blood which they receive during the period of their functional vigour, and from the manner in which this is distributed by minute capillary plexuses, on the exterior, and even through the interior, of the glandular vesicles, that it must be subservient

* See Mr. Simon's admirable "Physiological Essay on the Thymus Gland," from which the foregoing summary has been derived.

† That the fluid does *not* contain true Albumen in solution, but some albuminous compounds, is indicated by the results of Mr. Beale's analysis ("Cyclop. of Anat. and Physiol.," vol. iv. p. 1106.)

to some process of active change; and the aspect of the contents of these vesicles, as well as of the substance in which they are imbedded, indicates that cell-growth is rapidly proceeding, at the expense of the materials thus afforded. But, on the other hand, that the products of this cell-growth are *not* substances which, like those of the ordinary glands, must be separated from the Blood, either for *its* purification, or to serve some special purpose in the economy, appears from the fact that they are not carried off by ducts, but are received again into the current of the circulation. This would be equally true in the end, were these products discharged (as formerly supposed) by the Lymphatics; but such an idea is inconsistent with our present knowledge of the distribution of these vessels; and it may be considered next to certain that the matters, whatever their nature may be, which have been elaborated by these glandular organs, are received again through the capillaries into the Venous system. With the exception of the Spleen, all the ductless glands thus discharge their products at once into the general venous circulation; so that, after having passed through the lungs, they will be carried by the systemic arteries through the system at large: but the splenic vein, it will be remembered, forms one of the roots of the portal trunk; and *its* blood must thus pass through the *liver*, before it enters the vena cava. For this exception, a reason may possibly be found in one of the offices which has been attributed to the Spleen.

489. Whatever materials, then, are withdrawn from the Blood by these organs, are returned to it again in an altered state; and that the change which they have undergone is one that prepares them for higher uses in the economy, may fairly be inferred from this circumstance. For as the blood which has received them is immediately transmitted to the system (except in the case of the splenic blood) without having passed through any other depurating organ than the lungs, it appears fair to conclude that the products which it has taken-up in these organs are either *combustive* or *nutritive*, *i.e.*, either serve to maintain the functional activity of the lungs, or of the system, or of the blood itself. Now that they are not destined to prepare a pabulum for respiration, appears from the very small quantity of fat which is found in their substance, except when their period of functional activity has gone by. On the other hand, the albuminous nature of the plasma, and the finely-granular appearance which it presents, strongly indicate that a material is here in progress of preparation, which is to be rendered subservient to the formative operations. Various facts which have been noticed in regard to the changes in the bulk of the Thymus in young animals (and particularly its rapid diminution in over-driven lambs, and its subsequent gradual re-distension during rest if plentiful nutriment be afforded), lead to the conclusion that such is almost undoubtedly the function of that body; and the close resemblance which it bears to the rest in every essential particular, seems to justify our extension of this inference to them.—But further, it does not seem at all unreasonable to suppose that these organs may be concerned, equally with the Absorbent glands, in supplying the germs of those cells which are ultimately to become Blood-corpuscles. Such, it is well known, was the doctrine of Hewson* in regard to the Spleen and

* See his Third Series of "Experimental Inquiries," Chaps. iii.-v.

Thymus gland; and there are many facts which lend it a considerable probability. In the first place, that there is no physical impossibility in the reception of particles of such a size into the interior of a closed system of capillaries, is proved by the very curious facts already noticed in regard to the passage of starch-grains into the mesenteric veins (§ 465). Secondly, many observers have noticed an unusual proportion of colourless corpuscles in the blood of the splenic vein.* Thirdly, the period of greatest functional activity of all these glands is during the state of early childhood, when the formative processes are going on with extraordinary activity; and there is at this time a larger proportion of colourless corpuscles in the blood, than at any subsequent period, at least in the healthy state. Further, as Prof. J. H. Bennett has pointed out, the peculiar condition of the blood, which consists in the multiplication of its colourless corpuscles (§ 175), is almost always associated with hypertrophy of one of these bodies; and in one case of this kind, in which the thyroid was the organ affected, its cells and their included nuclei were observed to be considerably smaller than usual, and the same peculiarity presented itself in the colourless corpuscles of the blood.† Hence there seems a strong probability, that whilst the plasma of the blood is being elaborated by these bodies, a constant supply of new blood-corpuscles is also afforded by them.‡

490. The peculiar position of the Spleen, in reference to the Portal circulation, however, seems to mark it out as having some special function of a supplemental character. Two out of the many theories of its action which have been advanced, deserve particular notice in connection with this point. Many experimenters have come to the conclusion, that, whatever may be the *other* purposes answered by the Spleen, it serves as a *diverticulum* to the Portal circulation, so as to relieve its vessels from undue turgescence, in virtue of the readiness with which it is distended with blood; and this under a great variety of circumstances. As the portal system is destitute of valves, the splenic vein has free communication with the whole of it; so that the Spleen will serve as a receptacle for the venous blood, when the secreting action of the Liver is feeble, so that the portal circulation receives a partial check. That any cause of obstruction to the hepatic circulation peculiarly affects the Spleen, has been proved by experiment; for after the Vena Portæ has been tied, the spleen of an animal, which previously weighed only 2 oz., has been found to weigh a pound and a quarter, or ten times as much. Further, it is evident that turgescence of the portal system is liable to occur, when the alimentary canal is distended with food; and this from two causes,—the pressure on the intestinal veins, and the quantity of fluid absorbed by these veins. Hence it may be conceived, that the Spleen, by affording a reservoir into which the superfluous blood may be directed, serves an

* For one of the most recent and satisfactory testimonies to this fact, see Funke in "Henle's Zeitschrift," 1851, p. 172.

† This fact is the more weighty, as, in another case observed by Prof. Bennett, the colourless corpuscles of the blood were of two distinct sizes, the smaller corresponding with the nuclei of the larger ones; and the *lymphatic glands* were found to be crowded with corpuscles also of two distinct sizes, exactly corresponding with those of the blood. (See "Edinb. Monthly Journal," October, 1851.)

‡ This view has been ably supported by Prof. J. H. Bennett in "Edinb. Monthly Journ.," March, 1852.

important purpose in preventing congestion of other organs. From the observations of Mr. Dobson,* it appears that the Spleen has its maximum volume at the time when the process of chymification is at an end,—namely, about five hours after food is taken; and that it is small and contains little blood seven hours later, when no food has been taken in the interval. Hence he inferred that this organ is the receptacle for the increased quantity of blood, which the system acquires from the food, and which cannot, without danger, be admitted into the blood-vessels generally; and that it regains its previous dimensions, after the volume of the circulating fluid has been reduced by secretion. This view is confirmed by the fact noticed by several observers,—that the Spleen rapidly increases in bulk after the ingestion of a large quantity of fluid, which is absorbed rather by the Veins than by the Lacteals. It has been further stated in support of this theory, that animals from which the Spleen has been removed, are very liable to die of apoplexy, if they take a large quantity of food at a time; but that, if they eat moderately and frequently, they do not suffer in this manner.—Now this doctrine derives its chief support from experiments on Ruminating and other Herbivorous animals, whose food is very bulky, and who ingest a large quantity of it at a time; and it is in them that the organ is most distensible, and that the splenic vein is best adapted, by the peculiar disposition of its coats, for the reception of a very large amount of blood. The *cellated* structure which forms a large part of the spleen in these tribes, is almost wanting in Man; and the fibrous envelope of his spleen, with its trabecular partitions, has very little either of elasticity or contractility. Nevertheless, there is evidence that an extraordinary accumulation of blood may take place in this organ even in him, from any cause which obstructs the passage of blood through the liver, or which impedes its return to the heart (as in Asphyxia, § 574), or which occasions a general internal venous congestion, such as occurs in the cold stage of intermittent fever. The peculiar liability of the Spleen to be distended with blood in this last condition, is shown by its permanent enlargement in those who have been long the subjects of such complaints.—Thus it appears that the Spleen may serve, independently of its primary function, as a sort of safety-valve to the portal circulation; and that its structure is most particularly adapted for such a purpose in those tribes of animals, which, from their habits of feeding, may be considered most specially to need an organization of this kind.

491. It is further maintained by Prof. Kölliker, that one function, at least, of the Spleen, is to dissolve the effete Red Corpuscles of the blood, and to prepare their Hæmatine for becoming the colouring matter of the Bile. This view is grounded upon the existence of the peculiar aggregations of cells resembling red corpuscles in a state of disintegration, of which mention has already been made (§ 482, IV.); and it seems to derive confirmation from the results of Béclard's analyses of the blood of the Splenic vein, which show a marked deficiency in the amount of red corpuscles, and an excess of the albuminous constituent, as compared with the blood of other parts (§ 168). It must be remembered, however, that such aggregations are by no means peculiar to the Spleen, but have been

* "London Med. and Phys. Journ.," Oct., 1820.

found in the substance of Muscles, Glands, and other organs; and although the peculiar conditions of the circulation in the Spleen may tend to produce them in unusual numbers, their formation can scarcely be regarded as one of the essential functions of the organ.*

## CHAPTER IX.

### OF THE CIRCULATION OF THE BLOOD.

#### 1.—*Of the Circulation in General.*

492. The Circulation of nutritive fluid through the body has for its object, on the one part, to convey to every portion of the organism the materials for its growth and renovation, together with the supply of Oxygen which is requisite for its vital actions, especially those of the Nervo-Muscular apparatus; and at the same time to carry off the particles which are set free by the disintegration or 'waste' of the tissues, and which are to be removed from the body by the Excreting processes. Of these processes, the one most constantly in operation, as well as most necessary for the maintenance of the purity of the blood, is the extrication of Carbonic acid, through the Respiratory organs; and this is made subservient to the introduction of Oxygen into the system. In Man, as in other Vertebrated animals, there is a regular and continuous movement of the nutritive fluid through the sanguiferous vessels; and upon the maintenance of this, the activity of all parts of the organism is dependent. In common with Birds and Mammals, again, Man has a Respiratory circulation entirely distinct from the Systemic; all the blood which has returned from the body being transmitted to the lungs, and being brought back to the heart again, before it is again sent forth for the nourishment of the tissues and for the maintenance of their functional activity. The Heart is placed at the junction of these two distinct circulations, which may be likened to the figure 8; and it may be said to be formed by the fusion of two distinct organs, a 'pulmonary' and a 'systemic' heart; for its right and left sides, which are respectively appropriated to these purposes, have no direct communication with each other (in the perfect adult condition, at least), and seem merely brought together for economy of material.† Each system has its own set of Arteries or efferent vessels, and of Veins or afferent trunks; these communicate at their central extremity by the Heart, and at their peripheral extremity by the Capillary vessels, which are nothing else than the minutest ramifications of the two systems, inosculating into a plexus (§ 292).—Besides the systemic and pulmonary circulations, however, there is another which is no less distinct, although it has not an impelling organ of its own. This is the 'portal' circulation, which is interposed between the venous trunks of the abdo-

* See Prof. J. H. Bennett in "Edinb. Monthly Journal," March, 1852, p. 211.

† At an early period of fœtal life, as in the permanent state of the Dugong, the heart is so deeply cleft, from the apex towards the base, as almost to give the idea of two separate organs.

minal viscera and the Vena Cava, for the purpose of distributing that blood through the Liver, in which organ its newly-absorbed materials undergo assimilation (§ 472), whilst its excrementitious matters are separated by the secreting process. The Vena Portæ, which is formed by the convergence of the gastric, intestinal, splenic, and pancreatic veins, subdivides again like an artery, so as to form a capillary plexus which extends through the whole substance of the liver; and the Hepatic vein, collecting the blood from this plexus, conveys it into the Vena Cava. Thus the portal circulation is grafted (so to speak) upon the general circulation, in precisely the same mode as the respiratory circulation is grafted upon it in Mollusca and Crustacea; and if the 'sinus' of the vena portæ had possessed contractile muscular walls, it would have ranked as the proper heart of the portal system. The really arterial character of the Vena portæ is well shown by comparing it with the Aorta of Fishes; which is formed by the convergence of the branchial veins, and then distributes the blood which it has received from them to the body generally.*

493. That the movement of the Blood through the arterial trunks and the capillary tubes, is, in Man, and in other warm-blooded animals, chiefly dependent upon the action of the Heart, there can be no doubt whatever. It can be easily shown by experiment, that if the arterial current be checked, the capillaries will immediately cease almost entirely to deliver the blood into the veins, and the venous circulation will be instantaneously arrested. And it has also been proved, that the usual force of the Heart is sufficient to propel the blood, not only through the arterial tubes, but through the capillaries, into the veins; since even a less force will serve to propel warm water through the vessels of an animal recently dead.† But there are certain "residual phenomena" even in Man, which clearly indicate that this is not the whole truth; and that forces existing in the Blood-vessels themselves have a considerable influence, in producing both local and general modifications of the effects of the Heart's action. There are also indications of the existence of an influence in which the blood-vessels do not partake, arising from those changes occurring between the blood and the tissues, that constitute the processes of Nutrition, Secretion, &c. Such, for instance, would appear to be the interpretation of the fact, that whilst any variations in the action of the Heart affect the whole system alike, there are many variations in the Circulation, which, being very limited in their extent, cannot be attributed to such central disturbances, and must therefore be dependent on causes purely local.—Of the nature of these influences, and of the mode of their operation, the most correct idea may be obtained by examining the phenomena of the Circulation in those beings, in which the moving power is less concentrated than it is in the higher Animals; for we find that in Plants and the lowest Animals, as in the earliest embryonic state of the highest, a movement of nutritious fluid takes place through a system of minute passages or channels excavated in the tissues (representing a *capillary* plexus), without any *vis a tergo* derived from an impelling organ. Ascending a little higher in the series, we meet with a system of vascular *trunks*, distributing the

* For an account of the principal modifications of the Circulating apparatus in the Animal Kingdom, see "Princ. of Phys., Gen. and Comp.," pp. 677–710.

† See Dr. Williams's "Principles of Medicine," 2nd edit., p. 185, *note*.

blood to these plexuses, and collecting it again from them; and the walls of these trunks are so far endowed with contractility, as to assist, by a sort of peristaltic movement, in the maintenance of the current through them. Still passing upwards, we find this contractility manifesting itself especially in some limited portion or portions of the vascular system, which execute regular movements of contraction and dilatation; and this tendency to concentration is observed to increase, until the whole movement is subordinated to the action of a principal propelling organ, the Heart.*—We shall now examine what agency in the Human Circulation may be attributed to the Heart, the Arteries, and the Veins respectively; and what other forces may be fairly presumed to operate in the Capillary circulation.

### 2.—*Action of the Heart.*

494. The Heart is endowed in an eminent degree with the property of *irritability;* by which is meant, the capability of being easily excited to movements of contraction alternating with relaxation (§ 315). Thus, after the Heart has been removed from the body, and has ceased to contract, a slight irritation will cause it to execute, not one movement only, but a series of alternate contractions and dilatations, gradually diminishing in vigour until they cease. The contraction begins in the part irritated, and then extends to the rest. It appears from Mr. Paget's experiments,† that it is necessary for the propagation of this irritation, that the parts should be connected by muscular tissue, of which a very narrow isthmus will suffice; and that the propagation will not take place, if the connecting isthmus be composed of tendon, even though this be a portion of the auriculo-ventricular ring, which has been supposed by some to be peculiarly efficacious in this conduction.—That the irritability of the Heart is not dependent upon the Cerebro-spinal system, appears not merely from the manifestation of it when the organ is altogether removed from the body; but also from the fact, that if the flow of blood through the lungs be kept up by artificial respiration, the heart's action will continue for a lengthened period, even after the Brain and Spinal Cord have been removed, and when animal life is, therefore, completely extinct. Hence we see that the Irritability of this organ must be an endowment properly belonging to itself, and not derived from that portion of the Nervous System.‡ Like the contractility of other muscles, it can only be sustained for any great length of time, by a supply of Arterial blood to its own tissue (§ 323, 324). It is much less speedily lost in cold-blooded animals, however, than in warm-blooded; the heart of the Frog, for example, will go on pulsating for many hours after its removal from the body; and it is stated by Dr.

* See the Author's "Princ. of Phys., Gen. and Comp.," CHAP. XII.

† "Brit. and For. Med. Review," vol. xxi. p. 551.

‡ It was formerly supposed, that the movements of the Heart were dependent upon its connection with the centres of the Cerebro-Spinal nervous system: and the experiments of Legallois and others, who found that they were arrested by crushing, or otherwise suddenly destroying, large portions of these centres, appeared to favour the supposition. But it has been shown by Dr. Wilson Philip and his successors in the same inquiry, that the whole Cerebro-Spinal axis might be *gradually* removed, without any such consequence; which fact harmonizes perfectly with the "experiments prepared for us by Nature," in the production of monsters destitute of these centres, which nevertheless possessed a regularly-pulsating heart.

Mitchell * that the heart of a Sturgeon, which he had inflated with air, continued to beat, until the auricle had absolutely become so dry, as to rustle during its movements. It has further been shown by Mr. Tod, that the irritability of the heart is of long duration after death in very young animals: which, as long since demonstrated by Dr. Edwards, agree with the cold-blooded Vertebrata in their power of sustaining life, for a lengthened period, without oxygen.

495. It is difficult to account for the long continuance of the alternate contractions and relaxations of the muscular parietes of the Heart, after all evident stimuli have ceased to act upon it; and many theories have been offered on the subject, none of which afford an adequate explanation. The extraordinary tendency to *rhythmical* action, which distinguishes the heart from nearly all other muscles (§ 318, *note*), is shown by the fact, that not only do the entire hearts of cold-blooded animals continue to act, long after their removal from the body, but even separated portions of them will contract and relax with great regularity for a long time. Thus the auricles will persist in their rhythmical action, when cut off above the auriculo-ventricular rings; and the apex of the heart will do the same, when separated from the rest of the ventricle. The stimulus of the contact of blood with the lining membrane of the heart, to which its regular actions have been commonly referred, can have no influence in producing such movements; nor does it appear that the contact of *air* can take its place; since, as Dr. J. Reid has shown, the rhythmical contractions of the heart of a frog will continue *in vacuo*.† Nor is there any evidence that the flow of blood through the cavities has the effect of securing the regularity of their successive contractions in the living body; for this regularity is equally marked in the contractions of the excised heart, when perfectly emptied of blood, so long as its movements continue vigorous. But when its irritability is nearly exhausted, the usual *rhythm* is often a good deal disturbed, so that the contractions of the auricles and ventricles do not regularly alternate with each other; and one set frequently ceases before the other. — The difficulty of finding any other satisfactory solution of the problem, has recently led many Physiologists to recur to the idea that the Heart's action is dependent upon Nervous power; this power being supposed to be derived, however, not from the Cerebro-spinal system, but from the ganglia of the Sympathetic system which are found in the organ itself. For the proper estimation of the evidence favourable to this view, it is requisite that we should bring together the principal facts which indicate the relation of the Heart's action to Nervous influence, from whatever source this proceeds.

496. It has been asserted by Valentin and other experimenters, that mechanical irritation of the Pneumogastric nerves, especially at their

* "American Journal of the Medical Sciences," vol. vii. p. 58; see also Prof. Dunglison's "Human Physiology," 7th edit., vol. ii. p. 149.

† "Cyclopædia of Anatomy and Physiology," vol. ii. p. 611.—This experiment has been since repeated by Prof. Tiedemann ("Müller's Archiv.," 1847) and by Drs. Mitchell and Bache (Prof. Dunglison's "Human Physiology," vol. ii. p. 150) with a different result; the pulsations being speedily brought to a stand by the exhaustion of the air, and being renewed when it was re-admitted. This, however, does not invalidate the positive fact that the pulsation *may* continue *in vacuo*, which proves that the stimulus of air cannot be its maintaining power; and only shows that the presence of oxygen is essential to the continuance of the heart's movements, as to muscular action in general (§ 324).

roots, has a tendency to excite or accelerate the heart's action; numerous experimenters, however, have obtained none but negative results. Admitting, what seems probable, that the Cardiac branches of the Pneumogastric have some influence upon the Heart's action, it remains to inquire whether that influence be essential to its movements; and whether these nerves form the channel through which they are affected by emotions of the mind, or by conditions of the bodily system. In regard to the first point, no doubt can be entertained; since the regular movements of the heart are but little affected by section of the Pneumogastrics. With respect to the second, there is more difficulty; since the number of causes, which may influence the rapidity and pulsations of the heart, is very considerable. For, example, when the blood is forced-on more rapidly towards the heart, as in exercise, struggling, &c., its contractions are rendered more frequent; and when the current moves on more slowly, as in a state of rest, their frequency becomes proportionably diminished. If the contractions of the heart were not thus in some degree dependent upon the blood, and their number were not regulated by the quantity flowing into its cavities, very serious and inevitably fatal disturbances of the heart's action would soon result. That this adjustment takes place otherwise than through the medium of the nervous centres, is evident from the fact, that, in a dog, in which the Pneumogastric and Sympathetic had been divided in the neck on each side, violent struggling, induced by alarm, raised the number of pulsations from 130 to 260 per minute.* It is difficult to ascertain, by experiments upon the lower animals, whether simple emotion, unattended with struggling or other exertion, would affect the pulsation of the heart, after section of the Pneumogastrics; but when the large proportion of the Sympathetic nerves proceeding to this organ is considered, and when it is also remembered that irritation of the roots of the upper cervical nerves stimulates the action of the heart through these, we can scarcely doubt that both may serve as the channels of this influence, especially in such animals as the dog, in which the two freely inosculate in the neck.—Although there is a difficulty in proving that the Heart's action can be excited or accelerated by irritation of the Pneumogastrics, yet these nerves may serve as the channel of an influence of a very opposite character; for the experiments of MM. Weber have shown that its movements may be immediately arrested by the transmission of the electric current from a rotating magnet, either through the Spinal Cord, or through the Pneumo-gastrics divided at their origin; the same irritation, however, applied to a single one of the Vagi, produced no effect.† Hence it is obvious that the influence of sudden and violent injury to the Cerebro-spinal centres, which induces an immediate diminution or suspension of the Heart's mechanical movements, or even entirely annihilates them, may be conveyed through these trunks, as well as through the Sympathetic system (§ 321).

497. In like manner it may be shown that the Heart's action may be affected by influences transmitted through the Sympathetic system of nerves. There is considerable difficulty in obtaining direct experimental evidence to this effect, of a satisfactory character; but there is strong

* See Dr. J. Reid's "Anat. Phys. and Path. Researches," p. 170.

† "Archives d'Anat. Génér., et de Physiol.," Jan., 1846; and "Wagner's Handwörterbuch," Art. 'Muskelbewegung.'

reason to believe that the effects of *shock* may be exerted no less directly through the Sympathetic than through the Cerebro-spinal system (§ 321); and that considerable disturbance may ensue from lesions of such parts of it (at least) as are most nearly connected with the heart. Thus a case has been put on record, in which the heart's pulsations were occasionally checked for an interval of from 4 to 6 beats, its cessation of action giving rise to the most fearful sensations of anxiety, and to acute pain passing up to the head from both sides of the chest,—these symptoms being connected, as it proved on a post-mortem examination, with the pressure of an enlarged bronchial gland upon the great cardiac nerve.* It is not less obvious, however, in regard to the principal centres of the Sympathetic system, than with respect to those of the Cerebro-spinal, that in whatever degree the heart's action may be influenced through them, it cannot be dependent upon any power which it derives from them, since it continues after the complete isolation of the organ. And the very difficulty of obtaining experimental evidence of this influence, notwithstanding the extraordinary irritability of the Heart, seems to show that the ordinary movements of the organ are but little dependent upon nervous influence of any kind.—The only centres of nervous power, to which, consistently with the foregoing facts, the maintenance of the Heart's action can be attributed, are the numerous ganglia, forming part of the Sympathetic system, which are dispersed through its substance, but which are brought into connexion with each other by communicating fibres. These, it has been surmised, may act as centres of 'reflex' action; and may thus keep up the contractions of the heart, after its complete withdrawal from the influence of the Cerebro-spinal and of the principal Sympathetic centres, just as the ganglia contained in the separated segments of the body of a Centipede are centres of movement to the limbs with which they remain in connection. But this hypothesis does not give any real solution to the difficulty; for in every case of true 'reflex' action, the movement is excited by a stimulus; and no rhythmical succession of movements can be thus excited, save by the successive recurrence of stimuli at regular intervals, as in the act of Respiration. It is the continuance of activity after all conceivable sources of stimulation have been withdrawn, which constitutes the real perplexity of the case; and if the operation of such stimuli be admitted as the sources of *reflex* action, they may with equal propriety be regarded as *directly* acting upon the contractile fibre, —which, as already shown, is much more amenable to such direct excitation, than it is to nervous influence, and preserves its capacity for being impressed by the former during a much longer period than it remains capable of responding to the latter.

498. A more satisfactory mode of accounting for the rhythmical movements of the Heart, appears to the Author to lie in regarding them as an expression of the peculiar vital endowments of its Muscular tissue; and to believe that, so long as this tissue retains its integrity, and the other necessary conditions are supplied, so long is an alternation of contraction and relaxation the characteristic and constant manifestation of its vital

* "Müller's Archiv.," 1841, heft iii.; and "Brit. and For. Med. Rev.," Oct., 1841. It may be surmised that in many cases of *angina pectoris*, in which no lesion adequate to account for death could be discovered, some affection of the cardiac plexus might have been traced on more careful examination.

activity,—just as ciliary movement is in cells of one class, and secreting action in those of another (§ 110). The fact that this movement is seen to commence in the embryo-heart, when as yet its parietes consist of ordinary cells, and no nervous structure exists either in its own substance or in the body at large, is an important confirmation of this doctrine; whilst the same fact stands in complete opposition, to the idea, that nervous force is in any way concerned in maintaining this rhythmical action.—But it may be said that in attributing to the muscular structure of the heart a self-moving power, we really only throw back the question into the obscurity from which the Physiologist has sought to draw it.* Such is far from being the case, however, if it can be shown that this self-moving power is nothing else than an exertion of ordinary Muscular Contractility under peculiar conditions; and if analogous phenomena can be shown to present themselves elsewhere.† To this point attention will now be directed.

499. We have seen that the contraction of *any* Muscle, upon the application of a stimulus, must be attributed to an exercise of Vital Force engendered by previous acts of Nutrition. The stimulus is not the source of the force, but only supplies some condition which is requisite for its manifestation; just as the fall of a spark upon gunpowder causes its explosion (the force of which is the expression of the change in the chemical condition of its components, which change is dependent upon their pre-existing affinities), or as the application of the discharger to the Leyden jar (which has been charged by the previous action of the Electrical machine) liberates, so to speak, its pent-up electricity, and allows this to display itself as an active force. Now just as the Leyden jar may be so charged with electricity as to *dis*charge itself spontaneously, so is it easy to conceive that a Muscle may be so charged with *motility* (or motor force) as to execute spontaneous contractions; and of the existence of such a condition, we have valid evidence. For there are many local phenomena of cramp and spasm, which cannot be fairly attributed to a perverted reflex action of the nervous system, and which can scarcely be referred to anything else than an overcharge of muscular power. So, again, the action of the uterus, as shown not merely in the final parturient effort, but in local contractions that frequently occur during the later months of gestation (simulating the movements of the fœtus), are more satisfactorily accounted for by considering them as a discharge of accumulated power, than in any other mode (§ 110). And we have seen that muscles which are ordinarily excited to rhythmical movement through the medium of the nervous system, may execute these movements of themselves, when this source of stimulation has

* In so far as it attributes the Heart's action to causes originating in itself, this doctrine may be considered as nothing else than the old notion of the inherent 'pulsific virtue' of the organ, so happily ridiculed by Molière and Swift. But there is really just the same difference between the two, as between the doctrine of Vital Forces, which it has been the Author's object to unfold in this and the companion Treatise, and the old notion of the 'vital principle' which was held to account for everything not otherwise explicable.

† It cannot be too constantly borne in mind, in this and other instances, to *explain* a phenomenon in Physiology or in any other science whatever, is nothing else than to show that it is conformable to some general *law*, and that it is thus a result of some previously-recognized *cause*, which is common to it with a number of other previously-observed phenomena. (See Mr. John Mill's "System of Logic," book iii. chap. xii.)

een cut off, and their motility has accumulated through inaction (§ 318 *ote*).—It is not very difficult, then, to conceive, that the ordinary ıythmical movements of the heart may be due to a simple excess of ıis motility, which is continually being supplied by the nutritive operaons, and is as constantly discharging itself in contractile action. And ıat this is the true view of the case, is further indicated by the phenoıena attending the cessation of the heart's action. For if a stimulus be pplied to it soon after it has ceased to execute spontaneous movements, ıis stimulus is followed, not (as in ordinary muscles) by a single con-:action followed by relaxation, but by a succession of contractions and elaxations; thus indicating that a higher degree of motility than that of n ordinary muscle still persists in its tissue.* Gradually, however, the umber of repetitions becomes smaller and smaller, until the application f the stimulus excites but a single contraction; thus indicating that the ıotility of the heart has been reduced, by the cessation of the nutritive perations, to that of an ordinary muscle.—If we pass from this comarison of the Heart with other muscles, to the general phenomena of hythmical movement in the Animal and Vegetable kingdoms, the proof urnished by analogy that the immediate source of its action lies enirely within itself, becomes much stronger; but this part of the subject ıas been treated-of elsewhere.†

500. This view of the case is not in the least inconsistent with the act, that the ordinary rhythmical actions of the heart may be considerbly modified, both as to their rate and their force, by stimuli of various inds brought to bear upon its tissue, either through the nervous system, r by direct contact. Of the former we have an example in the influence f the emotions; and of the latter in the violent action excited by an ınusual rush of blood towards the heart, in consequence of sudden nuscular exertion.

501. When the Heart is exposed in a living animal, and its movements re attentively watched, they are seen to follow each other with great egularity. In an active and vigorous state of the circulation, however, hey are so linked together, that it is not easy to distinguish them into eriods; both Auricles contracting and also dilating simultaneously, and oth Ventricles doing the same. The *systole* or contraction of the Ventricles orresponds with the projection of blood into the arteries; whilst the *diastole* r dilatation of the Ventricles coincides with the collapse of the arteries. The contraction of the Ventricles, and that of the Auricles, alternate with ne another; each taking place (for the most part, at least), during the lilatation of the other. But there is a period during which the Auricles nd Ventricles of both sides are dilating together. This occurs during he first part of the Ventricular diastole; for at the conclusion of the ystole, the Auricles are far from being completely filled, and they go on eceiving an additional supply from the great Veins (a portion of which, however, passes at once into the Ventricles) until after the middle of the Ventricular diastole, by which time they become fully distended and immediately contract. The contraction of the Auricles is synchronous, therefore, with only the second stage of the Ventricular diastole; and their

* This is a phenomenon which has no parallel among any of the manifestations of proper *reflex* action.

† See § 110; also "Princ. of Phys., Gen. and Comp.," CHAP. XIX.

dilatation is going on during the whole period of the Ventricular systole. Thus whilst the entire period that intervenes between one pulsation and another is nearly equally divided between the systole and diastole of the Ventricles, the division is very unequal as regards the Auricles; scarcely more than one-eighth of the whole being occupied in their contraction, and the remainder being taken-up by their dilatation. The following tabular view will perhaps make the relations of the several parts of this series more intelligible.

| | Auricles. | Ventricles. | |
|---|---|---|---|
| $\frac{7}{8}$ | Dilatation. | Contraction. | $\frac{1}{2}$ |
| | Continued Dilatation. | First stage of Dilatation. | $\frac{1}{2}$ |
| $\frac{1}{8}$ | Contraction. | Second stage of Dilatation. | |

502. In the *systole* of the Ventricles, their surface becomes rugous; the superficial veins swell; the carneæ columnæ of the left ventricle are delineated; and the curved fibres of the conical termination of the left ventricle, which alone constitutes the apex of the heart, become more manifest.* During their contraction, the form of the Ventricles undergoes a very marked change, the apex of the heart being drawn up towards its base, and its whole shape becoming much more globular. The movement of the apex, however, is by no means a simple elevation; for, owing to the peculiar arrangement of the fibres of this part of the heart, it is made to describe a spiral curve from right to left, and from behind forwards. It is to this change in the form of the heart, and in the position of its apex, rather than to change in the place of the organ as a whole, that we are to attribute its *impulse* against the parietes of the chest; for if any advance and recedence do take place, from the various causes which have been assigned by different observers (such as the pressure of the blood in the direction opposite to that of the orifices through which it is being impelled, the tendency of the aorta to straighten itself when distended with blood, and the elastic recoil of the parts about the base of the heart), this must be extremely trifling in its amount, since all these causes require distension of the organ with blood for their operation, and the tilting-forward of the lower part of the heart still ensues when its apex has been cut off, and no such tension can be exercised.—The *diastole* of the ventricles, according to Cruveilhier (loc. cit.), has the rapidity and energy of an active movement; triumphing over pressure exercised upon the organ, so that the hand closed upon it is opened with violence. This is an observation of great importance; and it concurs with observations made upon the heart when emptied of blood, to show that the diastole is not a mere relaxation of the muscular fibres, permitting the cavity to be distended, but is effected by some power inherent in the walls themselves.† Even the dilatation of the Auricles appears to be much greater than can be accounted for by any *vis a tergo* (which, as will hereafter appear, is extremely small in the venous system), or by the

* See the account given by M. Cruveilhier of a remarkable case of Ectopia Cordis, in "Gazette Médicale," Août 7, 1841.

† The only power whose existence has been hitherto admitted, as competent to produce such an effect, is the *elasticity* of the tissues composing the walls of the heart. The Author would suggest, however, whether there may not exist in Muscle an active force of elongation, as well as an active force of contraction; arising from the mutual *repulsion* of particles whose mutual *attraction* is the occasion of the shortening.

lasticity of its substance; for it was observed in this case to be so great, hat the right auricle seemed ready to burst, so great was its distention, nd so thin were its walls. Moreover, the large veins near the heart conract simultaneously with the auricle, and not whilst it is dilating; so that hey can have no influence in causing its distention.

503. The course of the circulating fluid through the Heart, and the ction of its different valves, will now be briefly described.—The Venous lood, which is returned by the ascending and descending Vena Cava, nters the *right* Auricle during its diastole; part of it flows on, as already nentioned, into the right Ventricle during the earlier portion of its liastole; but the Auricle, being filled before the Ventricle, then contracts, nd discharges its contents through the tricuspid valves into the Ventricle, which it thus completely distends. The reflux of blood into the veins luring the auricular systole, is impeded by the contraction of their own valls, and by the valves with which they are furnished; but these valves re so formed, as not to close accurately, especially when the tubes are listended; so that a small amount of reflux usually takes place, and this s much increased when there is any obstruction to the pulmonary circuation. Whilst the *right* Ventricle is contracting upon the blood that has ntered it, the *carneæ columnæ*, which contract simultaneously with its roper walls, put the *chordæ tendineæ* upon the stretch; and these draw he flaps of the Tricuspid valve into the auriculo-ventricular axis. The lood then getting behind them, and being compressed by the contraction f the ventricle, forces the flaps together, in such a manner as to close he orifice; but they do not fall suddenly against each other, as is the ase with the semilunar valves, since they are restrained by the chordæ endineæ; whence it is, that no sound is produced by their closure. The lood is expelled by the ventricular systole into the Pulmonary Artery, hich it distends, passing freely through its Semilunar valves; but as oon as the *vis a tergo* ceases, and reflux might take place by the conraction of the arterial walls, the valves are filled-out by the backward endency of the blood, and completely check the return of any portion of into the ventricle. The blood, after having circulated through the ungs, returns as Arterial blood, by the Pulmonary Veins, to the *left* uricle; whence it passes through the Mitral valve into the *left* Ventricle, nd thence into the Aorta through its Semilunar valves,—in the same anner with that on the other side, as just described.

504. There are, however, some important differences in the structure nd functional actions of the two divisions of the Heart, which should be ere adverted to.—The walls of the *left* Ventricle are considerably thicker han those of the *right;* and its force of contraction is much greater. he following are the comparative results of M. Bizot's measurements,* aking the average of males from 16 to 79 years.

| | | BASE. | MIDDLE. | APEX. |
|---|---|---|---|---|
| Left Ventricle | . | $4\frac{1}{2}$ lines | $5\frac{1}{6}$ lines | $3\frac{3}{4}$ lines. |
| Right Ventricle | . | $1\frac{15}{16}$ lines | $1\frac{3}{8}$ lines | $1\frac{1}{30}$ lines. |

n the female, the average thickness is somewhat less. It will be een, that the point of greatest thickness in the *left* Ventricle is near its

* "Mém. de la Soc. Médic. d'Observation de Paris," tom. i.

middle; while in the *right,* it is nearer the base. The thickness of the former goes on increasing during all periods of life, from youth to advanced age; whilst that of the right is nearly stationary. The *left* Auricle is somewhat thicker than the *right;* the average thickness of the former being, according to Bouillaud, a line and a half; whilst that of the latter is only a line. In regard to the relative capacities of the right and left cavities, much difference of opinion has prevailed. The *right* Auricle is generally allowed to be somewhat more capacious than the *left;* and the same is commonly taught of the *right* Ventricle. So much fallacy may arise, however, from the peculiar condition of the animal at the moment of death, that this is not easily proved, and is indeed by no means certain.—The average capacity of the cavities may be estimated, in the full-sized Heart, at about three ounces; that of the Auricles being probably a little less; and that of the Ventricles a little greater. It has been shown that the Ventricles receive more blood from the Auricles, than the latter could transmit to them by simply emptying themselves once.—There is a well-known anatomical difference between the auriculo-ventricular valves on the two sides, which has given rise to the diversity of name. This seems, from the researches of Mr. King,* to be connected with an important functional difference. The Mitral valve closes much more perfectly than the Tricuspid; and the latter is so constructed, as to allow of considerable reflux, when the cavities are greatly distended. Many occasional causes tend to produce an accumulation of blood in the venous system, and in the right side of the Heart; thus, any obstruction to the pulmonary circulation, cold, compression of the venous system by muscular action, &c., are known to favour such a condition. This is a state of peculiar danger, from the liability which over-distention of the Ventricular cavity has, to produce a state of muscular paralysis; and in the structure of the Heart itself, there seems to be a provision against it. For, when the ventricle is thus distended, the Tricuspid valves do not close properly; and a reflux of blood is permitted, not only into the Auricle, but also (through the imperfect closure of their valves under the same circumstances) into the large veins. This is proved by the fact, several times observed by Dr. J. Reid in his experiments upon Asphyxia, &c., that, when the action of the right ventricle had ceased from over-distention, he could frequently re-excite it, not merely by puncturing its walls, but by making an opening in the jugular vein.† This fact evidently affords an indication of great importance in the treatment of Asphyxia; and it explains the reflux of blood, or *venous pulse,* which is frequently observed in cases of pulmonary disease, and which, according to Mr. King, always exists even in health, though in a less striking degree.

505. When the ear is applied over the cardiac region, during the natural movements of the Heart, two successive sounds are heard, each pair of which corresponds with one pulsation; there is also an interval of silence between each recurrence, and the sound that immediately follows this interval is known as the *first* sound, the other as the *second.*—The *first* sound is dull and prolonged; it is evidently synchronous with the impulse of the Heart against the parietes of the chest, and also with the pulse, as felt near the heart; it must, therefore, be produced during the

* "Guy's Hospital Reports," vol. ii. † Op. Cit., Chap. iii.

Ventricular Systole.—The *second* sound, which is short and sharp,* follows so immediately upon the conclusion of the first, that it cannot take place during the auricular systole as some have supposed, but must be assigned to the first stage of the ventricular diastole, when the auricles also are dilating. With regard to the relative duration of the two sounds and of the interval, widely different estimates have been formed. Thus Laennec considered the lengths of the periods of sound and silence to be respectively 3-4ths and 1-4th of the whole interval between one pulse and another; by Dr. Williams, and by Barth and Roger, the relative lengths of these periods have been estimated at 2-3rds and 1-3rd; whilst the recent experiments of Volkmann† (made by adjusting two pendulums to vibrate precisely in the two periods) indicate that they are almost precisely equal.

506. The cause of these sounds, and more especially of the *first*, has been a subject of much discussion. A number of very distinct actions are taking place during the period of its production; and each of these has been separately fixed-on as competent to produce it. Thus we have (*a*) the impulse of the heart against the parietes of the chest, (*b*) the contraction of the muscular walls of the ventricles, (*c*) the tension of the valves of the auriculo-ventricular orifices, and the backward impulse of the blood against them, (*d*) the rush of blood through the narrowed orifices of the aorta and pulmonary artery, and (*e*) the general molecular collision of the particles of the blood amongst each other, and their friction against the walls of the ventricles. Each of these causes has probably some share in the production of the result.

*a.* That the first sound is partly due to the *impulse*, seems proved by the fact, that when the impulse is prevented, by the removal of the portion of the wall of the chest against which it takes place, the sound is much diminished in intensity; and also by the circumstance, that, when the ventricles contract with vigour, the greatest intensity of the sound is over the point against which the impulse takes place. Moreover, the prolonged nature of the sound is by no means inconsistent with this view; since the impulse is not a mere stroke, so much as a continued pressure. But that the sound is not entirely due to this cause, is also evident from the fact, that it may still be heard when the heart is contracting out of the body, or when the impulse cannot take place.

*b.* That the sound is partly *muscular* (§ 330) would appear from the fact that it may be still perceived after the heart has been removed from the body and completely drained of its blood.‡ But that this is not its only source, is shown by the great diminution in its intensity, which is observable under such circumstances.

*c.* That the sudden *tension* of the auriculo-ventricular *valves*, with the reflux of the blood against them, at the commencement of the ventricular systole, is a cause of sound, would seem to be indicated by the analogy of the semilunar valves; and an experiment by Valentin,§ in which a sound in

* The difference between these two sounds is well expressed (as Dr. C. J. B. Williams has remarked) by articulating the syllables lubb, dŭp.

† "Die Hämodynamik, nach Versuchen," p. 364.

‡ See the Report of the London Committee upon the Sounds of the Heart, in the "Trans. of Brit. Assoc.," for 1836.

§ "Lehrbuch der Physiologie," band i. p. 427.

some degree resembling the first sound of the heart was produced by the impulse of fluid against a tense membrane, has been adduced in confirmation of this view. But it is to be borne in mind that these valves cannot close together with the same suddenness as do the semilunar, being restrained by the spring-like tension of the carneæ columnæ; and, moreover, even admitting a sound to be produced by their closure, such a sound would be momentary, and would not possess the prolonged character of the true first sound. Still it is not improbable that the tension of these valves serves to augment by resonance the sounds produced in other ways.

*d.* That the *rush of blood* through the narrowed orifices of the great arterial trunks is really a cause of sound, is indicated by the results of experiments made upon tubes out of the body, and upon large blood-vessels through which the blood is circulating; for any diminution of the calibre of a tube through which fluid is rapidly moving, gives rise to a continuous murmur. And that this cause is in operation in the heart, is specially indicated by the observations of Cruveilhier upon the case already cited; for he noticed that (the effect of the impulse being there in abeyance) the greatest intensity of the first sound was, like that of the second, at the base of the heart, in the region from which the great vessels originate, whilst he could discover no production of sound in the region of the auriculo-ventricular valves.

*e.* Lastly, that the *collision* of the particles of the blood with each other, and with the tense muscular parietes of the heart, together with its movement over the inequalities of the internal surface of the ventricle, will become a cause of sound, may be suspected from what happens elsewhere, and more especially from the production of a very distinct sound by the movement of blood in the interior of an aneurism;* but that this cause, if it have a real existence, is much inferior in potency to the preceding, appears from the fact that it cannot be distinguished from it; and that neither separately nor combined do these give a sufficient account of the phenomenon, is obvious from the persistence of a sound after the heart has been completely emptied of its blood.

507. It is only by thus regarding the first sound as made up by *several* factors, that we can adequately account for the operation of pathological causes in modifying it; since the greater part of the *bruits* and *murmurs* that are produced by morbid changes in the heart and in its valves, are really modifications of the natural sound, not additions to it.

508. That the *second* sound is produced in the act of closure of the Semilunar valves, is now almost universally admitted; the simple hooking-back one of these valves by a curved needle against the side of the artery, so as to permit a reflux of blood into the ventricle, being sufficient to suppress this sound altogether. Whether it proceeds from the tension of the valves themselves, or from the recoil of the blood against them, or from both causes combined, has not been clearly determined; probably the last is the true account of it.—When the first sound is altered by disease of the semilunar valves, occasioning obstruction to the exit of blood, the second sound also is affected in its character; and if the disease be of such a kind as to prevent these valves from effectually closing, a reflux of blood takes place into the ventricle at the time of its diastole,

* See the "Report of the Dublin Committee of the British Association," loc. cit.

causing a rushing sound analogous to the ordinary first sound, or to some of its modifications. Thus the second sound may come to acquire so completely the character of the first, that it is difficult to distinguish the two in any other way, than by the synchronousness of the first with the heart's stroke and with the pulse in the arteries.*

509. There seems adequate reason to believe that the whole, or very nearly the whole, of the blood contained in the Ventricles, is discharged from them at each systole; for the left ventricle is very frequently found quite empty after death; and if a transverse section be made through the heart, when in a state of well-marked *rigor mortis* (which may be considered as representing its ordinary state of complete contraction), the ventricular cavity is found to be entirely obliterated.† From the capacity of the cavity in its state of fullest dilatation, it can scarcely be admitted that more than 3 oz. of blood can be propelled by either ventricle at each systole;‡ and thus, if we estimate the whole amount of blood at 18 lbs. (§ 136), this would require 96 strokes for its passage through either side of the heart; or, reckoning 72 pulsations to a minute, the time elapsing before any particle could return to a given point after once passing it (supposing it not to be sent elsewhere), would be $1\frac{1}{3}$ minute. Between any such estimates, however, and those which are founded upon experimental inquiry into the time required for the passage of substances introduced into the circulating current from one part of the system to another, there is a discrepancy which it is very difficult to reconcile. The earliest of such experiments were those of Hering,§ who endeavoured to ascertain the rapidity of the circulation, by introducing prussiate of potash into one part of the system, and drawing blood from another. He states that he detected this salt, in blood drawn from one of the jugular veins of the Horse, within 20 or 30 seconds after it had been introduced into the other; in which brief space the blood must have been received by the heart, must have been transmitted through the lungs, have returned to the heart again, have been sent through the carotid artery, and have traversed its capillaries. From experiments of a similar nature upon other veins, he states that the salt passed from the jugular vein into the saphena in 20 seconds; into the masseteric artery in from 15 to 20 seconds; into the external maxillary artery in from 10 to 25 seconds; and into the metatarsal artery in from 20 to 40 seconds.‖ These

* On the subject of the Sounds of the Heart, the various treatises on Auscultation by Williams, Blakiston, Hughes, Walshe, Davis, Skoda, Barth and Roger, Weber, and others may be advantageously consulted; see also Dr. Bellingham's Lectures on Diseases of the Heart, in the "Medical Gazette" for 1850; the account of Hamernjk's investigations in the "Edinb. Monthly Journal," Jan., 1849; and those of Kiwisch in the "Brit. and For. Med.-Chir. Rev.," April, 1852.

† Kirkes and Paget's "Handbook of Physiology," 2nd edit., p. 80.

‡ The total quantity discharged from either ventricle of the human Heart at each systole, is estimated by Valentin at 5·3 oz., and by Volkmann at 6·2 oz.; but these amounts are deduced from calculation of the (supposed) total of the blood, divided by the estimated duration of its passage through the heart, rather than from actual admeasurement.

§ "Tiedemann's Zeitschrift," vol. iii. p. 85.

‖ Although attempts have been made to invalidate the inference which seems inevitably to flow from these experiments, in regard to the rate of the circulation, by attributing the transmission of the salt to the permeability of the animal tissues, yet it has never been shown that even prussiate of potash (which is probably at least as transmissible through this channel, as any other salt) can be carried from one part to another, with a rapidity at all proportional to

experiments have been fully confirmed by those of Poisseuille,* and also by those of Mr. Blake;† the latter of whom varied them by employing different substances, and took other precautions against sources of fallacy. At an interval of 10 seconds after having injected a solution of nitrate of baryta into the jugular vein of a horse, he drew blood from the carotid artery of the opposite side; after allowing this to flow for 5 seconds, he substituted another vessel, which received the blood that flowed during the 5 ensuing seconds; and the blood that flowed after the 20th second, by which time the action of the heart had stopped, was received into a third vessel. These different specimens were carefully analysed. No trace of baryta could be detected in the blood which had escaped from the artery between the 10th and the 15th second after the injection of the poison; but in that which was drawn between the 15th and the 20th second, the salt was found to be present, and in greater abundance than in the blood which had subsequently flowed. Moreover, the coincidence between the cessation of the Heart's action, and the diffusion of the salt through the arterial blood, bear a striking correspondence; and it may be hence inferred, that the arrestment of its muscular movement is due to the effect of this agent upon its tissue, when immediately operating upon it, through the capillaries of the coronary artery.—This conclusion is borne out by a variety of other experiments; which show that the time of the agency of other poisons that suddenly check the Heart's action (which is the especial property of *mineral* poisons), nearly coincides, in different animals, with that which is required to convey them into the arterial capillaries. And it seems to derive full confirmation from the fact, that poisons, which act locally on other parts, give the first indications of their operation, in the same period after they have been introduced into the venous circulation. Thus, in the Horse, the time that is required for the blood to pass from the jugular vein into the capillary terminations of the coronary arteries, is 16 seconds, as is shown by the power of nitrate of potass to arrest the Heart's action within that time; and nitrate of strychnia, injected into a vein, gave the first manifestation of its action on the Spinal Cord, in precisely the same number of seconds. In the Dog, the heart's action was arrested by the nitrate of potass in 11 or 12 seconds; and the tetanic convulsions occasioned by strychnia, also commenced in 12 seconds. In the Fowl, the former period was 6 seconds, and the latter $6\frac{1}{2}$; in the Rabbit, the first was 4, and the other $4\frac{1}{2}$ seconds.—From such experiments, it seems evident that the rapidity of the Circulation is underrated, in any estimate that we found upon the capacity of the Heart, and its number of pulsations in a given time; and it is difficult to see how the two sets of facts are to be reconciled.

510. The *force* with which the systemic Heart propels the Blood, may be estimated in two ways;—either by ascertaining the height of the column of that fluid, which its contractile action will support;—or by

this; and the only mode in which this property can be conceived materially to facilitate the transmission of the salt through the vascular system, would be by allowing it to pass through the septum of the auricles, and thus to make its way from the right to the left side of the heart, without passing through the pulmonary circulation; yet this it could scarcely do, to the large amount which is evidently transmitted, in so short a time.

* "Ann. des Sci. Nat.," 1843, Zool., tom. xix., p. 32.

† "Edinb. Med. and Surg. Journal," Oct., 1841.

causing the blood to act upon a shorter column of mercury.—The former method was the one adopted by Hales, who introduced a long pipe into the Carotid artery of a Horse, and found that the blood would sometimes rise in it to the height of 10 feet. From parallel experiments upon Sheep, Oxen, Dogs, and other animals, and by comparing the calibre of their respective vessels with that of the Human aorta, Hales concluded, that the usual force of the Heart in Man would sustain a column of blood $7\frac{1}{2}$ feet high, the weight of which would be about 4 lbs. 6 oz.—The second method is that which was adopted by Poisseuille; the result of whose experiments (made with the instrument which he termed the 'hæmadynamometer') corresponded very closely with that of Hales, his estimate of the pressure of blood in the aorta being 4 lbs. 3 oz. The more recent experiments of Volkmann* have led him to nearly the same conclusion; notwithstanding that he has pointed out certain fallacies in Poisseuille's method. The force which the walls of the Heart must exert, in order to impart such a pressure to the blood which they propel, is properly estimated by multiplying the pressure of blood in the aorta by the ratio between the area of that trunk and the surface of a plane passing through the base and apex of the left ventricle; which method of computation would make it about 13lbs.

511. The *number* of contractions of the Heart in a given time is liable to great variation, within the limits of ordinary health, from several causes; the chief of these are diversities of Age, of Sex, of Stature, of Muscular exertion, of the condition of the Mind, of the state of the Digestive system, and of the Period of the day.

*a.* Putting aside the other causes of uncertainty, the following table may be regarded as an approximation to the average frequency of the Pulse, at the several *Ages* specified in it, taking equal numbers of Males and Females.

| | BEATS PER MINUTE. |
|---|---|
| In the fœtus in utero | 140 — 150 |
| Newly-born infant | 130 — 140 |
| During the 1st year | 115 — 130 |
| During the 2nd year | 100 — 115 |
| During the 3rd year | 95 — 105 |
| From the 7th to the 14th year | 80 — 90 |
| From the 14th to the 21st year | 75 — 85 |
| From the 21st to the 60th year | 70 — 75 |
| Old age† | 75 — 80 |

*b.* The difference caused by *Sex* is very considerable, especially in adult age; it appears from the inquiries of Dr. Guy,‡ that the pulse of the adult Female exceeds in frequency the pulse of the adult Male, at the same mean age, by from 10 to 14 beats in a minute.

*c.* Many of the observations upon the effect of *Stature* upon the pulse, are invalidated by the neglect of other conditions in making them; it is

* "Die Hämodynamik nach Versuchen," CHAP. VII.

† The rise in the average frequency of the pulse in very advanced life, contrary to the prevalent notion, has been determined by the observations of Leuret and Mitivié ("De la Fréquence des Pouls chez les Aliénés"), Dr. Pennock ("Amer. Journ. of Med. Sci.," July, 1847), and Prof. Volkmann (Op. cit. p. 427.)

‡ "Guy's Hospital Reports," vol. iii. p. 312; and "Cyclop. of Anat. and Physiol.," Art. 'Pulse.'

affirmed by Volkmann, however, that a tolerably definite ratio exists,* the pulse being *cæteris paribus* less frequent as the stature is greater, so that if the pulse of a man of $5\frac{1}{2}$ feet high were 70 per minute, that of a man of 6 feet would be 66·7, and that of a man of 5 feet, 73·8.

*d.* The effect of *Muscular Exertion* in raising the pulse is well known; as is also the fact, which is one exemplification of it, that the pulse varies considerably with the *posture* of the body. The amount of this variation has been made the subject of extensive inquiry by Dr. Guy; and the following are his results. In 100 healthy Males, of the mean age of 27 years, in a state of rest, the average frequency of the pulse was, when standing 79, when sitting 70, and when lying 67 per minute. Several exceptions occurred, however, to the general law; and when these were excluded, the average numbers were, standing 81, sitting 71, and lying 66; so that the difference between standing and sitting was 10 beats, or 1-8th of the whole; the difference between sitting and lying was 5 beats, or 1-13th of the whole; and the difference between standing and lying was 15 beats, or 1-5th of the whole. In 50 healthy Females, of the same mean age, the average pulse when standing was 89, when sitting 81, and when lying 80; and when the exceptions (which were more numerous in proportion than in males) were excluded, the averages were, standing 91, sitting 84, lying 79; the difference between standing and sitting was thus 7 beats, or 1-13th of the whole; that between sitting and lying was 4, or or 1-21st of the whole; and that between standing and lying was 11, or 1-8th of the whole. In both sexes, the effect produced by change of posture increases with the usual frequency of the pulse; whilst the exceptions to the general rule are more numerous, as the pulse is less frequent. The variation is temporarily increased by the muscular effort, involved in the absolute change of the posture; and it is only by the use of a revolving board, by which the position of the body can be altered, without any exertion on the part of the subject of the observation, that correct results can be obtained. That the difference between standing and sitting should be greater than that between sitting and lying, is just what we should expect; when we compare the amount of muscular effort required in the maintenance of the two former positions respectively.

*e.* The pulse is well known to be much accelerated by *Mental excitement*, especially by that of the Emotions; it is also quicker during Digestion; but on neither of these points can any exact numerical statement be given.

*f.* The *diurnal* variation of the Pulse, has been made the subject of observation by Dr. Knox† and Dr. Guy;‡ whose inquiries concur to disprove the usual notion that the pulse rises towards evening, and make it appear that the more common fact is the reverse. It should not be laid down as a general rule, however, that the pulse is most frequent in the morning, unless it be also stated that the exceptions are very numerous. For, whilst out of *sixteen* healthy young persons of both sexes examined

* With his usual zeal for *formularization*, Volkmann expresses this ratio, as deduced from a large number of observations, by the ratio $p : p' = h'^{\frac{5}{9}} : h^{\frac{5}{9}}$;—$p$ being the rate of the pulse, and $h$ the height of the body. Or, in other words, the ratio is that of *the ninth root of the fifth power* of the height. Surely this is riding a hobby to the death.

† "Edinb. Med. and Surg. Journ.," vol. xi. p. 53.

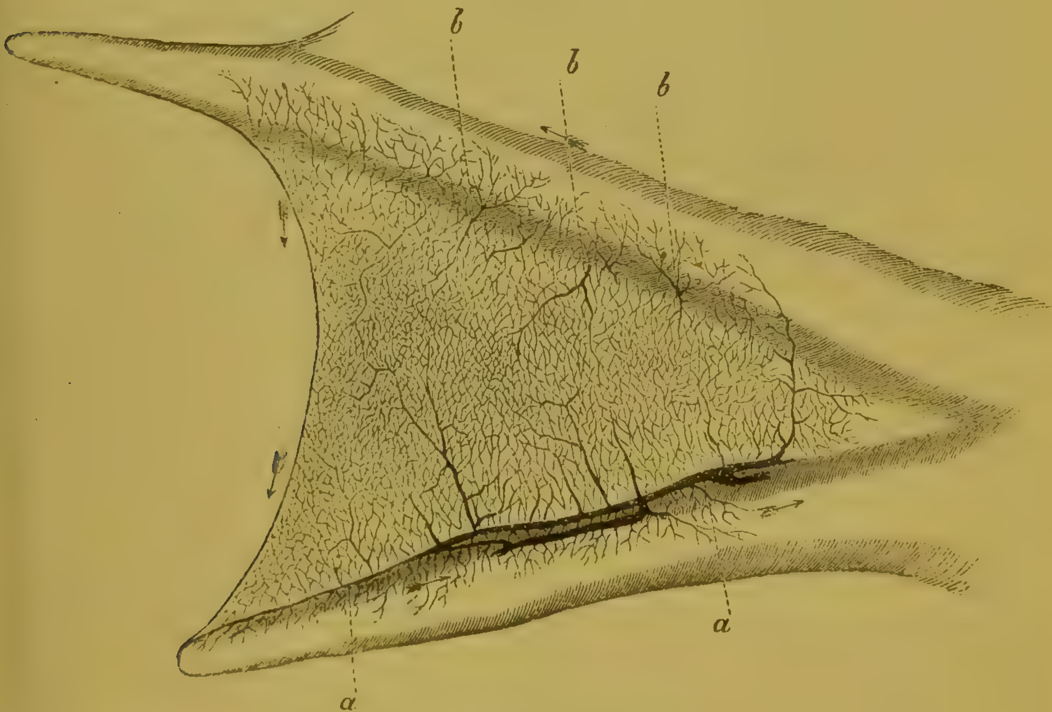
‡ "Guy's Hosp. Rep.," vol. iv. p. 69.

by Dr. Guy, the pulse was more frequent in the morning in *ten* individuals by from 2 to 18 beats per minute, it was more frequent in the evening in *four* individuals by from 9 to 13 beats, and in *two* others there was no difference. Both these experimenters have remarked, moreover, that the pulse is less excitable, as well as less frequent, in the evening than in the morning; thus, it was found by Dr. Guy that the very same food which in the morning increased the frequency of the pulse from 5 to 12 beats, and kept it raised above its natural number for one or two hours, produced no effect whatever in the evening; and it is a matter of ordinary experience that alcoholic liquors have a much more potent effect upon the circulation in the earlier than in the latter part of the day.

### 3.—*Movement of the Blood in the Arteries.*

512. The Blood propelled from the Heart is distributed to the body in general by a system of Arteries, which may be likened in its arrangement to the trunk and branches of a tree, except that very frequent communications or anastomoses exist among these branches, so that, by continual subdivision and inosculation, their distribution comes more and more to resemble the capillary network in which they terminate (Fig. 103).

FIG. 103.




Web of *Frog's foot*, stretching between two toes, magnified 3 diameters; showing the blood-vessels, and their anastomoses:—*a*, *a*, veins; *b*, *b*, *b*, arteries.

Although the *diameters* of the branches, at each subdivision, together exceed that of the trunk, yet there is but little difference in their respective *areas*. What difference does exist, however, is usually in favour of the branches; and thus it happens that there is a gradual increase in the capacity of the arterial system from its centre towards the capillaries, whose capacity is many times greater (§ 529).—The Arteries exert a most important influence upon the movement of blood through them, in virtue

of the physical and vital properties of their walls, or rather of their middle or fibrous coat, which alone is possessed of contractile properties. We find in this coat a layer of annular fibres, composed of muscular fibre-cells, mingled with areolar tissue.* On the outside of this, is a layer of yellow elastic tissue, which is much thicker in the larger arteries, in proportion to their size, than in the smaller. To this last tissue is due the simple *elasticity* of the arterial walls, which is a physical property that persists after death, until a serious change takes place in their composition; whilst to the one first mentioned, we are to attribute the property which they unquestionably possess (in common with proper muscular tissue) of *contracting* on the application of a stimulus, so long as their vitality remains. These two endowments are possessed in various proportional degrees, by the different parts of the Arterial system. Thus it was justly remarked by Hunter, that *elasticity*, being the property by which the interrupted force of the Heart is made equable and continuous, is most seen in the large vessels more immediately connected with that organ; whilst on the other hand, the *contractility* is most observable in the smaller vessels, where it is more required for regulating the flow of blood towards particular organs.

513. It has been denied by many Physiologists, that the middle coat of the Arteries possesses any property that can be likened to muscular *Irritability;* but no reasonable doubt can any longer exist on this point. That the walls of arteries cannot be readily stimulated to contraction through the medium of their nerves, is universally admitted; but the same is the case with regard to the muscular coat of the Alimentary canal, which contracts most vigorously on the direct application of stimuli to itself; and Valentin and others have succeeded in producing evident contractions in the Aorta, by irritation of the Sympathetic nerve, and of the roots of the cervical nerves of the Spinal system. Further, although many experimenters have failed in producing contractions of this tissue by stimuli directly applied to itself, yet such contractions may be so easily demonstrated by proper means, that the negative results cannot be admitted as invalidating the fact. It is of course in the smaller arteries, that the evidence of this contractility should be sought; and this may be readily obtained by observing the effects of various stimuli, mechanical, chemical, or electrical, upon the vessels of a transparent membrane, such as the bat's wing or the frog's foot. Thus if, whilst we watch the movement of blood in a companion artery and vein, we draw the point of a fine needle across them three or four times, without apparently injuring them or the membrane over them, they will both presently contract and close; then after remaining for a few minutes in the contracted state, they will begin again to dilate, and will gradually increase in diameter until they acquire a larger size than before the stimulus was applied. When in this condition, they will not again contract on the same stimulus as before; the needle may now be drawn across them much oftener and more forcibly, but no contraction ensues, or only a trivial one which is quickly followed by dilatation; with a stronger stimulus, however, such as that of great heat, they will again contract and close, and such contraction may last more than a day before the vessels

* Kölliker, in "Kölliker and Siebold's Zeitschrift," 1849.

again open and permit the flow of blood through them.*—The comparative effects of chemical and other stimuli have recently been especially studied by Mr. Wharton Jones,† by whom they are thus classified. (1). Constriction may slowly take place, and be slowly succeeded by the normal width; this is the action of the sulphate of atropia. (2.) Constriction may quickly take place, and be soon succeeded by the normal width, or a width not much exceeding the normal; this is the result of the moderate application of cold, and of mechanical and galvanic irritation. (3). Constriction either does not take place at all, or when it does, it very rapidly gives place to great dilatation; this is the effect of a weak solution of sulphate of copper, of a strong solution of common salt, of wine, of opium, and of spirit of wine. (4). Dilatation, preceded or not by momentary constriction, may slowly yield to constriction, which remains permanent; this is the effect of sulphate of copper, applied in strong solution, or in substance.—The electric stimulus is most effectual when applied by the magneto-galvanic apparatus; and the effects of such application have been especially studied by the Professors Weber.‡ When the minute arteries of the mesentery of frogs, between 1-7th and 1-17th of a Paris line in diameter, were thus stimulated, they did not immediately respond to the irritation, but began to contract after a few seconds, so that their diameter, in from five to ten seconds, was diminished by a third, and their sectional area consequently reduced to about half; by a continued application of the stimulus, their calibre was so much reduced, that only a single row of corpuscles could pass; and at last the vessels became completely closed, and the current of blood arrested, the original conditions being gradually restored on the cessation of the electric current.—Further, it has been ascertained by the careful experiments of Poisseuille (which confirm those of John Hunter) that when an artery is dilated by fluid injected into it, it reacts with a force superior to the distending impulse; and he has also shown that, if a portion of an artery from an animal recently dead (in which the vital contractility seems to be preserved), and one from an animal that has been dead some days (in which nothing but the elasticity remains), be distended with an equal force, the former becomes much more contracted than the latter, after the distending force is removed.

514. Several experiments also indicate the existence of that power of slow contraction in the arteries, which has been distinguished by the appellation *Tonicity* (§ 331). Thus, when a ligature is placed upon an artery in a living animal, the part of the artery beyond the ligature becomes gradually smaller, and is emptied to a certain degree, if not completely, of the blood it contained. Again, when part of an artery in a living animal is isolated by means of two ligatures, and is punctured, the blood issues from the orifice, and the inclosed portion of the artery is

* See Mr. Paget's 'Lectures on Inflammation,' in "Medical Gazette," June 7, 1850.—As Mr. Paget justly remarks, it is from the mechanical stimulus of the knife that small divided vessels contract and close, so as speedily to cease bleeding; but this contraction lasts only for a time; and hæmorrhage would commence on their dilatation, if their mouths were not sealed by coagula of blood or lymph. When secondary hæmorrhage does occur from want of such coagulation, it is most effectually controlled by the application of stimuli which, like the actual cautery, induce a more prolonged contraction of the vessels.

† 'Prize Essay on Inflammation,' in "Guy's Hospital Reports" for 1850, pp. 8, 9.

‡ "Müller's Archiv.," 1847.

almost completely emptied of its contents. Further, every Surgeon knows, that the contraction of divided arteries is an efficient means of the arrest of hæmorrhage from them, especially when they are of small calibre; so that, in the case of the temporal artery for example, the complete division of the tube is often the readiest means of checking the flow of blood from it, when it has been once wounded. This contraction is much greater than could be accounted for by the simple *elasticity* of the tissue; and is more decided in small, than in large vessels. The empty condition of the arteries, generally found within a short time after death, seems to be in part due to the same cause; since their calibre is usually much diminished, and is sometimes completely obliterated. A remarkable example of the same slow contraction, is that which takes place in the end of the upper portion of an arterial trunk, when the passage of blood through it is interrupted by a ligature; for the current of blood then passes off by the nearest large lateral branch; and the tube of the artery shrivels, and soon becomes impervious, from the point at which the ligature is applied, back to the origin of that branch. This last fact is important, as proving how little influence the *vis a tergo* possesses over the calibre of arterial tubes; since, without any interruption to the pressure of blood occasioned by it, the tube becomes impervious. It is to the moderate action of the *tonicity* of arteries, that their contraction upon the stream of blood passing through them (which serves to keep the tubes always full) is due. If the tonicity be excessive, the pulse is hard and wiry; but if it be deficient, the pulse is very compressible, though bounding, and the flow of blood through the arteries is retarded. Dr. C. J. B. Williams has performed some ingenious experiments (§ 532), which prove that the force required to propel fluid through a tube whose sides are yielding, is very much greater than that which will carry it through a tube of even smaller size, with rigid parietes; consequently, a loss of tonicity in the blood-vessels retards the flow of blood through them; whilst an increase hastens it.—We have seen that between the Irritability of arteries and their Tonicity, there is much less difference than exists in most other muscular structures; since the former is so long in manifesting itself, that it almost approaches to the character of the latter. But in the Arteries, as in other muscles, the *tonic* contraction may be most efficiently induced by *cold.* Thus Hunter observed that the exposure of an artery of a warm-blooded animal to the air for some time, would occasion its gradual contraction to such an extent as to effect the obliteration of its canal. This statement has been verified by many subsequent experimenters; and it has also been confirmed by the observations of Schwann upon the small arteries of the mesentery of frogs, which he caused to contract slowly by the application of cold water, and then saw dilate again; as much as half an hour being required, however, before they recovered their original size. On the other hand, the application of moderate warmth causes a relaxation of this tonic contraction.—And thus Cold and Heat are two of our most valuable remedial agents, when the Tonicity of the Vascular system is deficient or in excess.

515. We have now to inquire more closely into the influence exerted by the vital and physical properties of the walls of the Arteries, upon the motion of Blood through them.—There is no sufficient proof that the vital *Contractility* of these vessels enables them to exert a *propulsive* action in

any degree supplementary to that of the Heart; and yet, looking to the general facts already stated, as to the diffusion of the propulsive power through the arterial trunks in many of the lower animals (§ 493), and their experimentally-proved reaction upon a distending force, it does not seem by any means improbable that some such power should be preserved, even where there is the greatest concentration of the propulsive force in the muscular walls of the heart.—The contractility of the arteries seems to be chiefly exercised, however, in *regulating* the diameter of the tubes, in accordance with the quantity of blood to be conducted through them to any part; which will depend upon its peculiar circumstances at the time. Such local changes are continually to be observed, in the various phases of normal life, as well as in diseased states; and they will be found to be constantly in harmony with the particular condition of the processes of Nutrition, Secretion, &c., to which the capillary circulation ministers. In such cases, it cannot be the action of the Heart that increases the calibre of the vessels; since this is commonly unaltered, and is itself unable, as we have just seen, even to maintain their permeability, when their contractility is excited. It must, therefore, be by a power operating directly through themselves, that their dilatation is effected. The minute distribution of the Sympathetic nerve upon the walls of the arteries, the known power which this has of producing contractions in their fibrous coat (§ 513), and the influence of mental states upon their dimensions (as shown in the phenomena of blushing and erection), render it highly probable that the calibre of the arteries is regulated in no inconsiderable degree through its intervention. The *permanent* dilatation, however, which is seen in the arteries supplying parts that are undergoing enlargement, must be due, not to simple dilatation merely, but to increased nutrition; since we find that their walls are thickened as well as extended. And, on the other side, when slow contraction occurs in these tubes, as a consequence of disease, it must be in part occasioned by atrophy; since their nutrition is so much diminished, that in time they almost entirely disappear,—a portion of a large artery occasionally shrivelling into a ligamentous band.

516. The purpose served by the *Elasticity* of the Arteries, is one of a purely physical character; its effect being to convert the intermitting impulses, which the blood receives from the heart, into a continuous current. The former are very evident in the larger trunks; but they diminish with the subdivision of these, until they entirely disappear in the capillaries, in which the stream is usually equable or nearly so. If a powerful force-pump were made to inject water, by successive strokes, into a system of tubes with unyielding walls, the flow of fluid at the farther extremities of these tubes would be as much interrupted as its entrance into them. But if an air-vessel (like that of a fire-engine) were placed at their commencement, the flow would be in a great degree equalized; since a part of the force of each stroke would be spent upon the compression of the air included in it; and this force would be restored by the elasticity of the air during the interval, which would propel the stream, until directly renewed by the next impulse. A much closer imitation of the natural apparatus would be afforded by a pipe which had elastic walls of its own; thus if water were forced by a syringe into a long tube of caoutchouc, for example, the

stream would be equalized before it had proceeded far. This effect is found to be accomplished, at any point of the Arterial circulation, in a degree proportionate to its distance from the Heart; and in this mode it is, that the intermitting force of the ventricular contraction is almost equably distributed over the whole of the interval between one systole and another, by the contraction of the elastic tubes in the dilatation of which it was at first expended.—Another effect of this elasticity is to distribute the pressure of the blood upon the walls of the arteries, much more equally than would be the case if they formed a system of rigid tubes. For, according to Volkmann,* since the lateral pressure of a liquid moving through tubes of uniform calibre with rigid walls, is proportional to the resistance to be overcome at each point, and since this resistance depends upon the adhesion and friction between the liquid and the parietes of the tube, the lateral pressure at each point will vary inversely with the distance of that point from the discharging orifice. Consequently, if the arteries constituted a system of rigid tubes, the pressure on their walls would decrease very rapidly in passing from the heart towards their peripheral extremities. Such, however, is far from being the case (§ 519).

517. The distension of the Arteries consequent upon the intermittent injection of blood into their trunks, and the subsequent contraction which results from the elasticity of their walls, give rise to the *pulsation* which is perceptible to the touch in all but the smallest arteries, and is visible to the eye when they are exposed. This pulsation involves an augmentation of the capacity of that portion of the artery in which it is observed; and it would seem to the touch as if this were chiefly effected by an increase of diameter. It seems fully proved, however, that the increased capacity is chiefly given by the elongation of the artery, which is lifted from its bed at each pulsation, and, when previously straight, becomes curved; the impression made upon the finger by such displacement not being distinguishable from that which would result from the dilatation of the tube in diameter. A very obvious example of this upheaval is seen in the prominent temporal artery of an old person. The total increase of capacity was estimated by Flourens, from experiments upon the carotid artery, at about 1-23rd part; but it is affirmed by Volkmann (Op. cit., chap. xiv.) that this must not be considered by any means a constant ratio, since it varies in different arteries, and in the same artery under different circumstances.†—The distension of the arteries does not take place at the same moment over the whole body, but is propagated as a *wave* from the commencement to the point of

* "Hämodynamik," p. 38.

† The experiments of Volkmann have led him to believe, that the transverse dilatation is greater than the longitudinal; but these experiments were made under conditions so different from those of the living artery, that but little weight can, in the Author's opinion, be attached to them. It is to be remembered, however, that every increase in length augments the capacity only in a simple ratio; thus a tube of 21 inches in length will only contain *one-twentieth* more than a tube of 20 inches long, of the same diameter. On the other hand, every increase in diameter augments the capacity of the tube in the ratio of the square of that increase; thus the capacity of a tube of 21 lines in diameter will be to that of a tube of 20 lines as 441 : 400, or *one-tenth* more. Consequently, supposing the increase of *capacity* to take place equally in both directions, the increase in longitudinal *dimension* will be far more apparent than the *transverse* enlargement.

discharge. The passage of this wave was considered by Prof. E. H. Weber to be distinct from the act of propulsion of the fluid; but it has been shown by Volkmann (Op. cit., chap. x.) that they are one and the same. He has further shown that two systems of waves arise, when a fluid is driven through an elastic tube by intermitting impulses; one of these being in the fluid, and the other in the walls of the tube. These may propagate themselves with different velocities, and thus two undulations may result from one impulse. This want of coincidence between the two waves is probably the explanation of the *dichrotous* pulse, often observable in convalescence from fevers and other diseases after the subsidence of vascular excitement.—That a certain time is required for the transmission of the pulse-wave from the heart to the periphery of the circulation, is proved by the want of synchronism between the ventricular systole and the pulsation of the arteries in various parts of the body, the difference varying according to their distance from the heart. A considerable diversity in the amount of this interval is observable in different states of the arterial system; for, as Dr. C. J. B. Williams has pointed out,* when the tonicity is in excess, the arteries approach the condition of rigid tubes, and the pulse at the wrist is almost exactly synchronous with the heart's beat; whilst, if the tonicity be defective, the radial pulse is felt at a long interval after the heart's beat, and the difference is still more perceptible when the pulse is examined in the feet. The longest interval in a state of health seems to be between 1-6th and 1-7th of a second.

518. The *rate of movement* of the blood in the Arteries can only be guessed-at, as regards the Human subject, from the comparative results of experiments upon the lower animals. It is stated by Volkmann (Op. cit. p. 196) that the average velocity of the current in the carotids of a considerable number of Mammals which he examined, was about 300 millim., or nearly 12 inches, per second; that the velocity is greater in the arteries lying near, than in those at a distance from the heart; that it is not increased by an augmentation in the number of pulsations;† but that it is greatly augmented by an increase in the volume of the blood, and lessened by its diminution. It appears from the observations of the Profrs. Weber already referred-to (§ 513), that the velocity undergoes a marked increase in branches of arteries whose diameter has undergone diminution by the contraction of their walls, the acceleration

* "Principles of Medicine," 2nd edit., pp. 76, 77.—Dr. Williams mentions, what the Author has himself noticed, that the radial pulse, in cases of deficient tonicity, is sometimes felt *after* the second sound of the heart is heard; a fact that negatives the doctrine of the pulse put forward by Mr. Colt ("Medical Gazette," vol. xxxvi. p. 456), which was founded on the assumption that the pulse is perceived in every part of the arterial system previous to the occurrence of the second sound of the heart, that is, before the closure of the aortic valves. The Author has a very distinct recollection of a case which he witnessed when a student in the Middlesex Hospital, in which the radial pulse, though actually synchronous with the heart's beat, was really dependent upon the *preceding* ventricular systole; the whole of the interval between one systole and another being required for the transmission of the pulse-wave from the heart to the wrist, as was proved by tracing it from the centre towards the periphery of the arterial system. Now in this case, if the marked want of synchronism between the pulse at the wrist and in the neck had not excited attention, the synchronism between the radial pulse and the heart's beat would have passed as an ordinary occurrence, instead of being a very extraordinary phenomenon.

† On this very important point, the observations of Volkmann are in full accordance with the results of some of Hering's experiments performed with special reference to it (§ 509).

being proportionate to the narrowing of the tube, as might *a priori* be expected; a gradual retardation took place with the return of the artery to the original diameter; and when, as sometimes happened, the vessel dilated to more than its former dimensions, a positive diminution in the rate of movement of the blood was observable.

519. The *lateral pressure* of the blood against the walls of the arteries was affirmed by Poisseuille to be equal throughout the whole arterial system; but the more accurate experiments of Volkmann (made with Ludwig's 'kymographion,' which is a far more trustworthy instrument than the 'hæmadynamometer' of Poisseuille) have shown that this is far from being correct. The pressure of the blood, he remarks, is no constant magnitude, but is incessantly changing according to the stroke of the heart, the movements of respiration, and the muscular actions of the body generally. A gradual diminution of its amount, however, may be nearly constantly traced from the commencement of the arterial to the termination of the venous system; and this is to be partly accounted for by the increase in the calibre of the vascular system, which takes place as we pass from the arterial trunks to their ramifications (§ 512), and still more from the arterial to the venous system (§ 530); and partly by the diminution of resistance (which is the essential cause of the lateral pressure) as the blood moves onwards towards its point of discharge (§ 516). The following table presents the results of Volkmann's observations (Op. cit. p. 173) upon the relative lateral pressure at four points of the circulation in different animals, namely (I.) the carotid near its origin, (II.) a peripheral branch of the carotid or some other artery, (III.) a peripheral rootlet of a vein, and (IV.) the jugular vein.

| | I. | II. | III. | IV. |
|---|---|---|---|---|
| Goat . . | 135 | 126 | 41 | 18 |
| Horse . . | 122 | 97 | 44 | 21·5 |
| Calf . . | 165·5 | 146 | 27·5 | 9 |

A blood-pressure equivalent to a column of mercury 160 millim. (6·3 inches) in height was assumed by Poisseuille as the standard for all arteries and for all Mammalia, and therefore (by inference) for Man. It has been shown by Ludwig and Volkmann, however, that the range of variation is very wide, being in the carotid of the horse from 150 to 321, and being not less in other animals. Hence it is obvious that no precise specification can be laid-down upon this point.

### 4. *Motion of the Blood in the Capillaries.*

520. We now come to the last head of the inquiry into the powers which convey the blood through the capillary system;—that, namely, which concerns the agencies existing in the Capillaries themselves. Many discussions on this subject may be found in Physiological writings: and it has so immediate a bearing on one of the most important questions in Pathology,—the nature of Inflammation,—that it deserves the fullest attention. The chief question in debate, is the degree in which the Capillary circulation is influenced by any other agency than the contractile power of the Heart and Arterial system; some Physiologists maintaining, that this alone is sufficient to account for all the phenomena

of the Capillary circulation; and others asserting, that it is necessary to admit some supplementary force, which may be exerted either to assist, retard, or regulate the flow of blood from the Arteries into the Veins. We shall first consider what evidence there is of the existence of any such force; and, when led to an affirmative conclusion, we shall examine into its nature.—No physiological fact seems to the Author to be more clearly proved, than the existence, in the lower classes of Animals, as well as in Plants, of some power independent of a *vis à tergo*, by which the nutritive fluid is caused to move through their vessels.* This power seems to originate in the circulation itself, and to be closely connected with the state of the Nutritive and Secreting processes: since anything which stimulates these to increased energy, accelerates the movement; whilst any check to them occasions a corresponding stagnation. It may be convenient to designate this motor force, by the name of *capillary power;* it being clearly understood, however, that no *mechanical* propulsion is thence implied. On ascending the Animal scale, we find the power which, in the lower organisms, is diffused through the whole system, gradually concentrated in a single part; a new force, that of the Heart, being brought into operation, and the Circulation placed, in a greater or less degree, under its control. Still there is evidence, that the movement of blood through the capillaries is not entirely due to this; since it may continue after the cessation of the Heart's action, may itself cease in particular organs when the Heart is still acting vigorously, and is constantly being affected in amount and rapidity, by causes originating in the part itself, and in no way affecting the Heart.—The chief proofs of these statements will now be adverted to.

521. When the flow of blood through the Capillaries of a transparent part, such as the web of a Frog's foot, is observed with the Microscope, it appears at first to take place with great evenness and regularity. But on watching the movement for some time, various changes may be observed, which cannot be attributed to the Heart's influence, and which show that a certain regulating or distributive power exists in the walls of the capillaries, or in the tissues which they traverse. Some of these changes, involving variations in the *size* of the capillary tubes, have been already referred to (§ 292). Others, however, are manifested in great and sudden alterations in the velocity of the current; which cause a marked difference in the rates of the movement of the blood through the several parts of the area under observation. Sometimes this variation extends even to the entire reversal, for a time, of the direction of the movement, in certain of the transverse or communicating branches; the flow always taking place, of course, from the stronger towards the weaker current. Not unfrequently, an entire stagnation of the current in some particular tube, precedes this reversal of its direction. Irregularities of this kind, however, are more frequent when the Heart's action is partly interrupted; as it usually is by the pressure to which the tadpole or other animal must be subjected, is order to allow microscopic observations to be made upon its circulation. Under such circumstances, the varieties in the capillary circulation, induced by causes purely local, become very conspicuous; for when the whole current is nearly stagnated, and a fresh

* See "Princ. of Phys., Gen. and Comp.," CHAP. XII.

impulse from the heart renews it, the movement is not by any means uniform (as it might have been expected to be) through the whole plexus supplied by one arterial trunk, but is much greater in some of the tubes than it is in others; the variation being in no degree connected with their size, and being very different at short intervals.

522. The movement of the blood in the Capillaries of cold-blooded animals, after complete excision of the Heart, has been repeatedly witnessed. In warm-blooded animals, this cannot be satisfactorily established by experiment, since the shock occasioned by so severe an operation much sooner destroys the general vitality of the system; but it may be proved in other ways to take place. After most kinds of natural death, the arterial system is found, subsequently to the lapse of a few hours, almost or completely emptied of blood; this is partly, no doubt, the effect of the tonic contraction of the tubes themselves; but the emptying is commonly more complete than could be thus accounted-for, and must therefore be partly due to the continuance of the capillary circulation. It has been observed by Dr. Bennett Dowler,* that in the bodies of individuals who have died from yellow fever (such as exhibited the remarkable post-mortem movements already noticed, § 328), the external veins frequently become so distended with blood *within a few minutes* after the cessation of the heart's action, that, when they are opened, the blood flows in a good stream, being sometimes projected to the distance of a foot or more, especially when pressure was applied above the puncture, as in ordinary blood-letting. It is not conceivable that the slowly-acting tonicity of the arteries should have produced such a result as this; which can scarcely, therefore, be attributed to anything else than the sustenance of the capillary circulation by forces generated within itself. Further, it has been well ascertained that a real process of secretion not unfrequently continues after general or somatic death; urine has been poured out by the ureters, sweat exuded from the skin, and other peculiar secretions formed by their glands; and these changes could scarcely have taken place, unless the capillary circulation were still continuing. In the early embryonic condition of the highest animals, the movement of blood seems to be unquestionably due to some diffused power, independent of any central impulsion; for it may be seen to commence in the Vascular Area, before it is subjected to the influence of the Heart. The first movement is *towards*, instead of *from*, the centre; and even for some time after the circulation is fairly established, the walls of the Heart consist merely of cells loosely attached together, and can hardly be supposed to have any great contractile power.

523. The last of these facts may be said not to have any direct bearing on the question, whether the 'capillary power' has any existence in the adult condition; but the phenomena occasionally presented by the fœtus, at a later stage, appear decisive. Cases are of no very unfrequent occurrence, in which the heart is absent during the whole of embryonic life, and yet the greater part of the organs are well developed. In most or all of these cases, it is true, a perfect twin fœtus exists, of which the placenta is in some degree united with that of the imperfect one; and it has been

* "Researches, Critical and Experimental, on the Capillary Circulation," reprinted from the "New Orleans Medical and Surgical Journal," Jan. 1849.

customary to attribute the circulation in the latter to the influence of the heart of the former, propagated through the placental vessels. This supposition has not been disproved (however improbable it might seem) until recently; when a case of this kind occurred, which was submitted to the most careful examination by an accomplished anatomist;* and this decisive result was obtained, that it seemed impossible for the heart of the twin fœtus to have occasioned the movement of blood in the imperfect one, and that some cause present in the latter must have been sufficient for the propulsion of blood through its vessels. It was a very curious anomaly in this case, that the usual functions of the arteries and veins must have been reversed; for the Vena Cava, receiving its blood from the umbilical vein nearly as usual, had no communication with the Arterial system (the Heart being absent,) except through the systemic capillaries; to which, therefore, the blood must have next proceeded, returning to the placenta by the umbilical artery. This view of the course of the blood was confirmed by the fact, that the veins were everywhere destitute of valves.—It is evident that a single case of this kind, if unequivocally demonstrated, furnishes all the proof that can be needed, of the existence, even in the highest animals, of a 'capillary power;' which, though usually subordinate to the Heart's action, is sufficiently strong to maintain the circulation by itself, when the power of the central organ is diminished. In this, as in many other cases, we may observe a remarkable capability in the living system, of adapting itself to exigencies. In the acardiac Fœtus, the 'capillary power' supplies the place of the Heart, up to the period of birth; after which, of course, the circulation ceases, for want of due aeration of the blood. It has occasionally been noticed, that a gradual degeneration in the structure of the Heart has taken place during life, to such an extent that scarcely any muscular tissue could at last be detected in it, but without any such interruption to the circulation as must have been anticipated, if this organ furnished the sole impelling force.

524. Further, it is a general principle, unquestioned by any Physiologist, and embodied in the ancient aphorism *Ubi stimulus ibi fluxus*, that, when there is any local excitement to the processes of Nutrition, Secretion, &c., a determination of blood *towards* the part speedily takes place, and the motion of blood *through* it is increased in rapidity; and although it might be urged, that this increased determination may not be the effect, but the cause, of the increased local action, such an opinion could not be sustained without many inconsistencies with positive facts. For it is known that such local determinations may take place, not only as a part of the regular phenomena of growth and development (as in the case of the entire genital system at the time of puberty and of periodical heat, the uterus after conception, and the mammæ after parturition), but also as a consequence of a strictly local cause. Thus, the student is well aware that, after several hours' close application, there is commonly an increased determination of blood to the brain, causing a sense of oppression, a feeling of heat, and frequently a diminished action in other

* See Dr. Houston in the "Dublin Medical Journal," 1837. An attempt was made by Dr. M. Hall ("Edinb. Monthly Journal," 1843) to disprove Dr. Houston's inferences; but a most satisfactory reply was given by Dr. Houston, at the Meeting of the British Association, August, 1843, and published in the "Dublin Journal," Jan., 1844. See also "Edinb. Med. and Surg. Journ.," July, 1844.

parts; and, again, when the capillary circulation is being examined under the microscope, it is seen to be quickened by moderate stimuli, and to be equally retarded by depressing agents. All these facts harmonise completely with the phenomena, which are yet more striking in the lower classes of organized beings, and which are evidently in accordance with the same laws.

525. It is equally capable of proof, on the other hand, that an influence generated in the Capillaries may afford a complete check to the circulation in the part; even when the Heart's action is unimpaired, and no mechanical impediment exists to the transmission of blood. Thus, cases of spontaneous gangrene of the lower extremities are of no unfrequent occurrence, in which the death of the solid tissues is clearly connected with a local decline of the circulation; and in which it has been shown, by examination of the limb after its removal, that both the larger tubes and the capillaries were completely pervious; so that the cessation of the flow of blood could not be attributed to any impediment, except that arising from the cessation of some power which exists in the capillaries, and which is necessary for the maintenance of the current through them. The influence of the prolonged application of Cold to a part, may be quoted in support of the same general proposition; for, although the calibre of the vessels may be diminished by this agent, yet their contraction is not sufficient to account for that complete cessation of the flow of blood through them, which is well known to occur, and to terminate in the loss of their vitality. The most remarkable evidence on this point, however, is derived from the phenomena of *Asphyxia,* which will be more fully explained in the succeeding Chapter (Sect. 3). At present it may be stated as a fact, which has now been very satisfactorily ascertained, that, if admission of air into the lungs be prevented, the circulation through them will be brought to a stand, as soon as the air which they contain has been to a great degree deprived of its oxygen, or rather has become loaded with carbonic acid; and this stagnation will, of course, be communicated to all the rest of the system. Yet, if it have not continued sufficiently long to cause the loss of vitality in the nervous centres, the movement may be renewed by the admission of air into the lungs. Now, although it has been asserted, that the stagnation is due to a mechanical impediment, resulting from the contracted state of the lungs in such cases, this has been clearly proved not to be the fact, by causing animals to breathe a gas destitute of oxygen, so as to produce Asphyxia in a different manner; for the same stagnation results, as in the other case.

526. If the phenomena which have been here brought together, be considered as establishing the existence, in all classes of beings possessing a circulating apparatus, of a 'Capillary power,' which affords a necessary condition for the movement of the nutritious fluid, through those parts in which it comes into more immediate relation with the solids, the question still remains open, what is the nature of that power.—It is very doubtful whether the Capillaries possess true contractility; for although their diameter is subject to great variation, yet this may be due simply to the elasticity of their walls, which tends to keep them constantly contracted upon the stream of blood that passes through them; and there is no adequate proof that the alterations in their size, which are consequent

upon the local application of stimuli, proceed from any other source than the alteration in the quantity of blood delivered to them by the minute arteries, the very considerable alterations in whose calibre under such influences have been already described (§ 513). In the experiments of the Profrs. Weber (loc. cit.) the application of the electric stimulus to the capillaries produced no change in their diameter. Even supposing the capillaries, however, to possess such an independent contractility, this could not exert itself in aiding the flow of blood through them, except either by rhythmical alternations of contraction and dilatation, or by some kind of peristaltic movement; and observation completely negatives the idea of the existence of any such movement, since the stream of blood, now rendered continuous by the elasticity of the arteries, passes through the capillaries as through tubes of glass. Hence the notion of any *mechanical* assistance, afforded by the action of the walls of the Capillaries to the movement of blood through them, must be altogether dismissed.—There is experimental evidence, however, that the movement of the blood may be affected by any agency which alters the chemico-vital relations between the blood and the tissues which it permeates. Thus, when the interrupted electric current was applied to the capillaries by the Profrs. Weber, they noticed that the blood-corpuscles showed a remarkable tendency to adhere to each other and to the walls of the vessels, so as to produce a great amount of friction and a consequent retardation; the continual arrival of new corpuscles thus produces an accumulation which completely fills the vessels of the part, and thus occasions a total stagnation; but this gives place to the renewal of the current, by the dispersion of the corpuscles, soon after the withdrawal of the stimulus. A very similar set of phenomena has been observed by Mr. Wharton Jones,* as the consequence of the direction of a stream of carbonic acid against the capillary network. And the depression of the vitality of the part, by such injuries as tend to excite Inflammation in it, produces a like stagnation. This effect cannot be attributed to mechanical obstruction in the vessels, for they are usually dilated, rather than contracted, when this condition exists; and without any change in the dimensions of a tube, the stream of blood through it may be seen decreasing from extreme velocity to complete stagnation.†—That alterations in the chemical state of the blood (involving, of course, important changes in its vital properties) are capable of exercising a most important effect on the Capillary circulation, is shown, not merely by the stagnation of the *pulmonary* Circulation in Asphyxia (§ 574), but by the curious fact ascertained by Dr. J. Reid,‡ that the blood, when imperfectly arterialised, is retarded in the *systemic* capillaries, causing an increased pressure on the walls of the arteries. He found that, when the ingress of air through the trachea of a Dog was prevented, and the Asphyxia was proceeding to the stage of insensibility,—the attempts at inspiration being few and laboured, and the blood in an exposed artery being

* "Brit. and For. Med. Review," vol. xiv. p. 600.

† See Mr. Paget, loc. cit., p. 971. — The Author had long previously satisfied himself that such was the fact; and is glad to be able to cite the far more extended observations of Mr. Paget on this point, in confirmation of his own.

‡ "Edinb. Med. and Surg. Journ.," April, 1841; and "Anat., Phys., and Pathol. Researches," chap. ii.

quite venous in its character,—the pressure upon the arterial walls, as indicated by the hæmadynamometer applied to the femoral artery, was much greater than usual. Upon applying a similar test to a vein, however, it was found that the pressure was proportionably diminished; whence it became apparent, that there was an unusual obstruction to the passage of venous blood through the systemic capillaries. After this period, however, the mercury in the hæmadynamometer applied to the artery began to fall steadily, and at last rapidly, in consequence of the diminished force of the heart, and the retardation of the blood in the pulmonic capillaries; but, if atmospheric air was admitted, the mercury rose *instantly*, showing that the renewal of the proper chemical state of the blood, restored the condition necessary for its circulation through the capillaries.*

527. It appears from the preceding facts, that the conditions under which the power in question uniformly operates, may be thus simply and definitely expressed: Whilst the injection of blood *into* the Capillary vessels of every part of the system, is due to the action of the Heart, its rate of passage *through* those vessels is greatly modified by the degree of activity in the processes, to which it should normally be subservient in them;—the current being rendered more rapid by an increase in their activity, and being stagnated by their depression or total cessation. Or at any rate, to use the more guarded language of Mr. Paget (loc. cit.), "we have facts enough to justify such an hypothesis, as that there may be some mutual relation between the blood and its vessels, or the parts around them, which, being natural, permits the most easy transit of the blood, but, being disturbed, increases the hindrances to its passage."—A physical principle which has been put forth by Prof. Draper,† which seems quite adequate to explain these phenomena. It seems fully capable of proof that "if two liquids communicate with one another in a capillary tube, or in a porous or parenchymatous structure, and have for that tube or structure different chemical affinities, movement will ensue; that liquid which has the most energetic affinity will move with the greatest velocity, and may even drive the other liquid before it." Now Arterial blood,—containing oxygen with which it is ready to part, and being prepared to receive in exchange the carbonic acid which the tissues set free,—must obviously have a greater affinity for those tissues, than Venous blood, in which both these changes have already been effected. Consequently, upon mere physical principles, the arterial blood which enters the Systemic capillaries on one side, must drive before it, and expel on the other side of the network, the blood which has become venous whilst traversing it; but if the blood which enters the capillaries have no such affinity, no such motor power can be developed.—On the other hand, in the Pulmonary capillaries the opposite affinities prevail. The venous blood and the air in the cells of the lungs have a mutual attraction, which is satisfied by the exchange of oxygen and carbonic

* This last fact (as Dr. Reid has remarked) is sufficient to negative the idea of Mr. Erichsen, that the obstruction is caused by the *contraction* of the capillaries under the stimulus of venous blood ("Edinb. Med. and Surg. Journ.," Jan., 1845); for all experiments agree in showing that such contraction can only be excited by the application of a stimulus for some minutes, and that relaxation takes place still more slowly (§ 513).

† "Treatise on the Forces which produce the Organization of Plants," pp. 22–41.

acid that takes place through the walls of the capillaries; and when the blood has become arterialised, it no longer has any attraction for the air. Upon the very same principle, therefore, the venous blood will drive the arterial before it, in the pulmonary capillaries, whilst respiration is properly going on: but if the supply of oxygen be interrupted, so that the blood is no longer aerated, no change in the affinities takes place whilst it traverses the capillary net-work; the blood continuing venous, still retains its need of a change, and its attraction for the walls of the capillaries; and its egress into the pulmonary veins is thus resisted, rather than aided, by the force generated in the lungs.—The change in the condition of the blood, in regard to the relative proportions of its oxygen and carbonic acid, is the only one to which the Pulmonary circulation is subservient; but in the Systemic circulation, the changes are of a much more complex nature, every distinct organ attracting to itself the peculiar substances which it requires as the materials of its own nutrition, and the nature of the affinities thus generated being consequently different in each case. But the same law may be considered to hold good in all instances. Thus the blood conveyed to the Liver by the portal vein, contains the materials at the expense of which the bile-secreting cells are developed; consequently the tissue of the liver, which is principally made up of these cells, possesses a certain degree of affinity or attraction for blood containing these materials; and this is diminished, so soon as they have been drawn from it into the cells around. Consequently the blood of the portal vein will drive before it, into the hepatic vein, the blood which has traversed the capillaries of the portal system, and which has given up, in doing so, the elements of bile to the solid tissues of the liver.

528. It can be scarcely doubted that it is by some influence exercised over the molecular actions, to which the blood is subject in the capillaries, that the Nervous system can operate on the functions of Nutrition, Secretion, &c. (§§ 381, 385); and this influence can scarcely be considered in any other light, than as a peculiar manifestation of vital force (§ 352). The following experiment made by Dr. Wilson Philip, exhibits the effect of 'shock' upon the capillary circulation. "The web of one of the hind legs of a frog was brought before the microscope; and while Dr. Hastings observed the circulation, which was vigorous, the brain was crushed by the blow of a hammer. The vessels of the web *instantly* lost their power, the circulation ceasing; an effect which cannot arise, as we have seen, from the ceasing of the action of the heart. [Dr. P. here refers to experiments, by which it was ascertained, that the circulation in the capillary vessels of the frog will continue for several minutes, after the interruption of the heart's action.] In a short time the blood again began to move, but with less force. This experiment was repeated, with the same result. If the brain is not completely crushed, although the animal is killed, the blow, instead of destroying the circulation, increases its rapidity."* We are not hence to conclude, however, that the Nervous system supplies any influence which is essential to the continuance of the Circulation; since it is only by such sudden and severe injuries to the nervous centres, as instantaneously destroy the vitality of the whole system (§ 321), that the

* "Experimental Inquiry into the Laws of the Vital Functions," 4th edition, p. 52.

movement of the blood is arrested.—The experiments of Müller and others satisfactorily prove, that the ordinary action of the Nerves does not produce any direct effect upon the capillary circulation; and this corresponds with the well-known fact, that the Nutritive processes may continue as usual after this action has been suspended. All the facts, which bear upon the question of the connection between Nervous agency and the forces maintaining the capillary circulation, have an equal relation to the functions of Nutrition and Secretion in general; and, as already shown, the Nervous system also influences these, by the control it exerts over the diameter of the blood-vessels (§ 515).

529. The average *rate of movement* of the blood through the capillary system may be determined with tolerable precision by microscopic measurement; and the observations of Hales, Valentin, and Weber concur in representing it to be from 1 inch to $1\frac{1}{2}$ inch per minute in the systemic capillaries of the Frog; 1·2 inch per minute, or ·02 inch per second, being about the average. In warm-blooded animals, however, the capillary circulation is probably much more rapid than this; the observations of Volkmann upon the mesenteric arteries of the Dog make its rate about ·03 inch per second, or 1·8 inch per minute; and it seems reasonable to suppose that the exposure of the membrane to the cool air would produce a considerable reduction in the normal rapidity of the flow of blood through it. Assuming ·03 inch per second, however, as the rate, and comparing this with the rate of movement of the blood in the larger arteries, which seems on the average to be 11·8 inches per second, it is calculated by Volkmann that the aggregate area of the capillaries (being in an inverse ratio to the rate of the blood's movement through them) must be nearly *four hundred* times that of the arterial trunks which supply them.*

## 5.—*Motion of the Blood in the Veins.*

530. The Venous system takes its origin in the small trunks that are formed by the re-union of the Capillaries; and it returns the blood from these to the Heart. The structure of the Veins is essentially the same with that of the Arteries; but the fibrous tissue of which their middle coat is made up, bears more resemblance to the areolar tissue of the skin, than it does to the true elastic tissue; and the muscular fibre-cells are usually much fewer in number, and are sometimes wanting altogether.† The *elasticity* of the Veins is shown by the jet of blood which at first spouts out in ordinary venesection, when, by means of the ligature, a distension has been occasioned in the tubes below it. A slight *contractility* on the application of stimuli, and on irritation of the Sympathetic nervous fibres, has been observed; but this is not so decided as in the arteries. The whole capacity of the Venous system is considerably greater than that of the arterial; the former is usually estimated to contain from 2 to 3

* "Hämodynamik," pp. 184, 204.

† The following, according to Prof. Kölliker, are veins which are unprovided with muscular structure:—The veins of the uterine portion of the placenta; the veins of the cerebral substance; the sinuses of the dura mater; Breschet's veins of the bones; the venous cells of the corpora cavernosa in the male and female; and probably the venous cells of the spleen. ("Kölliker and Siebold's Zeitschrift," 1849).

times as much blood as the latter, in the ordinary condition of the circulation; and when we consider the great proportion, which the Veins in almost every part of the body bear to the arteries, we shall scarcely regard even the larger of these ratios as exaggerated. Of course the rapidity of the movement of the blood in the two systems, will bear an inverse ratio to their respective capacities; thus if, in a given length, the veins contain three times as much blood as the arteries, the fluid will move with only one-third of the velocity. Even at their origins in the capillary plexus, the veins are larger than the arteries which terminate in the same plexus; so that, wherever the arterial and venous networks form distinct strata, they are readily distinguished from each other. The Veins are remarkable for the number of *valves* which they contain, formed of duplicatures or loose folds of the internal tunic, between the component laminæ of which, contractile fibres are interposed; and also for the dilatations behind these, which, when distended, give them a varicose appearance. The valves are single in the small veins, the free edge of the flap closing against the opposite wall of the vein; in the larger trunks they are double; and in a few instances they are composed of three flaps. The object of these valves is evidently to prevent the reflux of blood; and we shall presently see, that they are of important use in assisting in the maintenance of the venous circulation. They are most numerous in those veins, which run among parts affected by muscular movement; and they are not found in the veins of the lungs, of the abdominal viscera, or of the brain.

531. The movement of the blood through the Veins is, without doubt, chiefly effected by the *vis a tergo* or propulsive force, which results from the action of the heart and arteries; this, as already shown (§ 519) is very greatly diminished by the time that it acts on the blood in the veins; but the resistance to the onward movement of the blood is now so slight, that a very feeble power is adequate to overcome it. There are some concurrent causes, however, which are supposed by some to have much influence upon it, and of which the consideration must not be neglected.—One of these, is the *suction-power* attributed to the Heart; acting as a *vis a fronte*, in drawing the blood towards it. It is doubtful how far the Auricles have such a power of active dilatation, as that which would be required for this purpose; and no sufficient evidence has been given that the current of blood at any distance from the Heart is affected by it. Indeed, for a reason to be presently stated, this may be regarded as impossible.—Another important agency has been found by some Physiologists, in the *inspiratory movement;* this is supposed to draw the blood of the Veins into the chest, in order to supply the vacuum which is created there, at the moment of the descent of the diaphragm. That the movement in question has *some* influence on the flow of venous blood into the chest, is evident from the occurrence of the *respiratory pulse*, long ago described by Haller; which may be seen in the veins of the neck and shoulder in thin persons, and in those especially who are suffering from pulmonary diseases. During Inspiration, the Veins are seen to be partially emptied: whilst during Expiration they become turgid, partly in consequence of the accumulation from behind, and of the check in front; and partly (it may be) in some cases, through an absolute reflux from the veins within the chest (§ 504). The fact that, in the immediate neighbourhood of the chest, the flow of blood towards the heart

is aided by inspiration and impeded by expiration, is further proved by Sir D. Barry's experiment, which consisted in introducing one extremity of a tube into the jugular vein of a Horse, and the other into water, which exhibited an alternate elevation and depression with inspiration and expiration; this has been repeated and confirmed by several Physiologists. On the other hand, the *expiratory* movement, while it directly causes accumulation in the veins, will assist the heart in propelling the blood into the arteries; and by the combined action of these two causes is produced, among other effects, the rising and sinking of the Brain, synchronously with expiration and inspiration, which are observed when a portion of the cranium is removed. Several considerations, however, agree in pointing to the conclusion, that no great efficacy can be rightly attributed to the Respiratory movements, as exerting any *general* influence over the Venous circulation. The Pulmonary circulation, being entirely within the chest, cannot be affected by variations in atmospheric pressure; the entire venous circulation of the fœtus, also, is independent of any such agency. Again, it has been shown experimentally by Dr. Arnott and others, that no suction-power exerted at the farther end of a long tube, whose walls are so deficient in firmness as are those of the Veins, can occasion any acceleration in a current of fluid transmitted through it; for the effect of the suction is destroyed, at no great distance from the point at which it is applied, by the flapping-together of the sides of the vessels.—One of the most powerful of the general causes which influence the Venous circulation, is doubtless the frequently-recurring *pressure of the muscles* upon their trunks. In every instance that Muscular movement takes place, a portion of the Veins of the part will undergo compression; and as the blood is prevented, by the valves in the veins, from being driven back into the small vessels, it is necessarily forced on towards the heart. As each set of muscles is relaxed, the veins compressed by it fill-out again, to be again compressed by the renewal of the force. That the general Muscular movement is an important agent in maintaining the circulation, at a point above that at which it would be kept by the action of the heart and vascular system alone, appears from several considerations. The pulsations are diminished in frequency by rest, accelerated by exertion, and very much quickened by violent effort (§ 511 *d*). In all kinds of exercise, and in almost every sort of effort, there is that alternate contraction and relaxation of particular groups of Muscles, which has been just mentioned as affecting the flow of blood through the veins; and there can be little doubt, that the increased rapidity of the return of blood through them, is of itself a sufficient cause for the accelerated movements of the heart. When a large number of muscles are put in action after repose, as is the case when we rise up from a recumbent or a sitting posture, the blood is driven to the heart with a very strong impetus; and if that organ should be diseased, it may arrive there in a quantity larger than can be disposed of; so that sudden death may be the result. Hence the necessity for the avoidance of all sudden and violent movements, on the part of those, who labour under either a functional or structural disease of the centre of the circulation.

532. The Venous circulation is much more liable than the Arterial, to be influenced by the force of Gravity; and this influence is particularly noticeable, when the tonicity of the vessels is deficient.—The following

ˑxperiments performed by Dr. C. J. B. Williams,* to elucidate the influ-ˑnce of deficient firmness in the walls of the vessels, and of gravitation, ˑver the movement of fluids through tubes, throw great light on the auses of *venous congestion.* A tube with two equal arms having been tted to a syringe, a brass tube two feet long, having several right angles n its course, was adapted to one of them, whilst to the other was tied a ortion of a rabbit's intestine four feet long, and of calibre double that of he brass tube, this being arranged in curves and coils, but without angles nd crossings. When the two tubes were raised to the same height, the mall metal tube discharged from two to five times the quantity of water ischarged in a given time by the larger but membranous tube; the dif-rence being greatest, when the strokes of the piston were most forcible nd sudden, by which the intestine was much dilated at its syringe-end, ut conveyed very little more water. When the discharging ends were aised a few inches higher, the difference increased considerably, the mount of fluid discharged by the gut being much diminished; and when ie ends were raised to the height of eight or ten inches, the gut ceased to ischarge, each stroke only moving the column of water in it, and this ubsiding again, without rising high enough to overflow. When the force f the stroke increased, the part of the intestine nearest the syringe burst. –From these experiments it is easy to understand, how any deficiency of tone' in the Venous system will tend to prevent the ascent of the blood om the depending parts of the body, and will consequently occasion an creased pressure on the walls of the vessels, and an augmentation in the uantity of blood they contain. All these conditions are peculiarly vourable to the escape of the watery part of the blood from the small essels; and this may either infiltrate into the areolar tissue, or it may be oured into some neighbouring serous cavity, producing dropsy. Thus it appens, that such effusions may often be traced to that state of deficient igour of the system, which peculiarly manifests itself in want of tone of ie blood-vessels; and that it is relieved by remedies which restore this. n many young females of leuco-phlegmatic temperament, for example, iere is a tendency to swelling of the feet, by œdematous effusion into the reolar tissue, in consequence of the depending position of the limbs; the dema disappears during the night, but returns during the day, and is at s maximum in the evening. And the congestion which frequently anifests itself in the posterior parts of the body, towards the close of hausting diseases, in which the patient has lain much upon his back, is tributable to a similar cause; of such congestion, effusions into the rious serous cavities are frequent results; and such effusions, taking ace during the last hours of life, are often erroneously regarded as the ause of death. To the same cause we are to attribute the varicose state the veins of the leg, which is so common amongst persons of relaxed re, and especially in those whose habits require them to be much in ie erect posture; and this distension occasionally proceeds to complete pture, the causes of which are fully elucidated by the experiments just ted.

* "Principles of Medicine," 2nd edit., p. 188.

### 6.—*Peculiarities of the Circulation in different Parts.*

533. In several portions of the Human body, there are certain varieties in the distribution and in the functional actions of the blood-vessels, which should not be omitted in a general account of the Circulation.—Of these, we have in the first place to notice the apparatus for the *Pulmonary* circulation; the chief peculiarity of which is, that *venous* blood is sent *from* the heart, through a tube which is arterial in its structure, whilst *arterial* blood is returned *to* the heart, through a vessel whose entire character is that of a vein. The movement of the blood through these is considerably affected by the physical state of the lungs themselves; being retarded by any causes, which can occasion pressure on the vessels (such as over-distension of the cells with air, obstruction of their cavity by solid or fluid depositions, or by foreign substances injected into them, &c.); and proceeding with the greatest energy and regularity, when the respiratory movements are freely performed.—The *Portal* circulation, again, is peculiar, in being a kind of offset from the general or systemic circulation, and also in being destitute of valves; and it may be surmised with much probability, that the purpose of their absence is, to allow of an unusually free passage of blood from one part of that system to another, during the very varying conditions to which it is subjected (§ 490).—Another very important modification of the Circulating system, is that which presents itself within the *Cranium.* From the circumstance of the cranium being a closed cavity, which must be always filled with the same total amount of contents, the flow of blood through its vessels is attended with some peculiarities. The pressure of the atmosphere is here exerted, rather to keep the blood in the head, than to force it out; and it might accordingly be inferred, that, whilst the quantity of cerebral matter remains the same, the amount of blood in the cranial vessels must also be invariable. This inference appeared to derive support from the experiments of Dr. Kellie.* On bleeding animals to death, he found that, whilst the remainder of the body was completely exsanguine, the usual quantity of blood remained in the arteries and veins of the cranium; but that if an opening was made in the skull, these vessels were then as completely emptied as the rest. It is not to be hence inferred, however, that the absolute quantity of blood within the cranium is not subject to variation; and that in the states of inflammation, congestion, or other morbid affections, there is only a disturbance of the usual balance of the arterial and venous circulation. The fact in all probability is rather, that the softness of the Cerebral tissue, and its varying functional activity, render it peculiarly liable to undergo alterations in bulk; and that the amount of the 'cerebro-spinal fluid' varies considerably at different times; so that the quantity of blood may thus, even in the healthy condition, be continually changing. Moreover, in disordered states of the circulation, the quantity of blood in the vessels of the cranium may be for a time diminished by a sudden extravasation, either of blood or serum, into the cerebral substance; and the amount of interior *pressure* upon the walls of the vessels may also be considerably

* "Edinburgh Medico-Chirurgical Transactions," vol. i.

ltered, even when there is no difference in the *quantity* of fluid contained ı them.*

534. The *Erectile* tissues constitute another curious modification of the ·dinary vascular apparatus. The chief of these are the corpora cavernosa ı the penis of the male, and in the clitoris of the female; the collection similar tissues round the vagina, and in the nymphæ, of the female; ıd the nipple in both sexes. In all these situations, erection may be roduced by local irritation; or it may take place as a result of certain notional conditions of the mind; the influence of which is probably ansmitted through the Sympathetic nerve, as it may be experienced even cases of paraplegia. The erectile tissue appears essentially to consist of plexus of veins with varicose enlargements, inclosed in a fibrous en- lope with trabecular partitions. This envelope, according to the recent searches of Prof. Kölliker, contains a large amount of non-striated uscular fibre; the contraction of which is doubtless in some way con- rned in the result. In the penis, as first pointed out by Prof. Müller, ıere are two sets of arteries; those of one set, destined for the nutrition the tissues, communicating with the veins in the usual way, through a pillary network; whilst the others, termed by him the 'helicine arteries,' e short tendril-like branches, which project into the veins (covered, how- er, by their lining membrane), sometimes singly, and sometimes in tufts, ıding abruptly by dilated extremities. It was maintained by Müller ıat the dilated ends of these helicine arteries open into the venous ıvities; but no distinct apertures have been seen in them; and it seems ore probable that (as Müller himself admits) they are merely arterial *verticula,* the distension of which concurs with that of the venous colæ, in the act of erection.—The proximate cause of the erection of the nis, has been stated by some to be the action of the ischio-cavernosi uscles; and by others it has been attributed to the compression of the na dorsalis penis against the symphysis pubis. But although these uscles probably afford assistance in completing and strengthening the ection, it is obvious that no analogous power can be exerted in other ectile organs, the nipple for example.—It is maintained by Prof. Köl- ker, that the office of the muscular fibres which pass in every direction nongst the dilated veins, is to keep them compressed in the intervals of ection, so as to prevent them from being distended by the *vis a tergo* of ıe blood; and that the stimulus to erection, which is usually conveyed ırough the nervous system, so operates upon these fibres as to occasion ıeir *relaxation,* whereby the free distension of the cavernous veins and of ıe arterial diverticula is permitted. He refers, moreover, to the exces- ve contraction of erectile organs which is induced by cold, and to the fect of warmth in favouring their enlargement, as confirmatory of this ew; and considers that no other agency is required.†

* The results of the more recent experiments of Dr. G. Burrows ("Medical Gazette," pril and May, 1843) fully confirm the views stated above.

† See his essay "Das Anatomische und Phisiologische Verhalten der Cavernöser Körper r Sexual organe," 1851; cited in Paget and Kirkes's "Hand-book of Physiology," 2nd it., p. 145.—It is rather difficult to admit the power of nerves to cause *relaxation* of uscles, which this hypothesis requires; and also to explain in accordance with it the fact of ry familiar occurrence, that the application of *moderate* cold (as in putting-on a clean shirt) quently occasions erection of the male nipple.

# CHAPTER X.

## OF RESPIRATION.

### 1.—*Nature of the Function: and Provisions for its Performance.*

535. The Nutritive fluid, in its circulation through the capillaries of the system, undergoes great alterations, both in its physical constitution, and in its vital properties. It gives up to the tissues with which it is brought into contact, some of its most important elements; and, at the same time, it is made the vehicle of the removal, from these tissues, of ingredients which are no longer in the state of combination that fits them for their offices in the Animal Economy. To separate these ingredients from the general current of the circulation, and to carry them out of the system, is the great object of the Excretory organs; and it is very evident that the importance of their respective functions will vary with the amount of the ingredient which they have to separate, and with the deleterious influence which its retention would exert on the welfare of the system at large. Of all these injurious ingredients, Carbonic Acid is without doubt the one most abundantly introduced into the nutritive fluid; and it is also most deleterious in its effects on the system, if allowed to accumulate. —We find, accordingly, that the provision for the removal of this substance from the blood, is one of peculiar extent and importance, especially in the higher forms of animals; and further, that instead of being effected by an operation peculiarly *vital* (like other acts of Excretion), its performance is secured by being made to depend upon simple *physical* conditions, and is thus comparatively little susceptible of derangement from disorder of other processes. All that is requisite for it, is the exposure of the Blood to the influence of the Atmospheric air (or, in aquatic animals, of air dissolved in water), through the medium of a membrane that shall permit the 'diffusion of gases;' an interchange then taking place between the gaseous matters on the two sides,—Carbonic acid being exhaled from the Blood, and being replaced by Oxygen from the air. Thus the extrication of Carbonic acid is effected in a manner that renders it subservient to the introduction of that element which is required for all the most active manifestations of vital power; and it is in these two processes conjointly, not in either alone, that the function of Respiration essentially consists.— We shall now inquire into the sources from which Carbonic acid is produced in the living body, and the causes of the demand for Oxygen.

536. It has been shown (chap. iii.) that the vital activity of the organism at large involves a continual change in its constituent parts; and that those which (so to speak) live the fastest, usually die the soonest, and pass most readily into decay. Hence in the very performance of the Organic functions which concur to effect the Nutrition of the body, there is a constant source of disintegration; and one of the chief products of the decay of the tissues, which is consequent upon their loss of vitality, is Carbonic acid.—Thus the *most general* object of the Respiratory process,

hich is common to all forms of organized being, is the extrication of this roduct from the system; and the demand for aeration hence arising will ary with the activity of the nutritive operations. Now the rate of life, nd consequently the amount of disintegration, in any organized strucure, depend in great measure upon the temperature at which it is mainained (§§ 123, 127); and thus it happens that the production of Carbonic cid from this source, at the ordinary rate of vital activity, is much more apid in 'warm-blooded' than in 'cold-blooded' animals, and that the ormer suffer far more speedily than the latter from the privation of air. But when the temperature of the Reptile is raised by external heat to the evel of that of the Mammal, its need for respiration increases, owing to he augmented waste of its tissues. When, on the other hand, the warmblooded Mammal is reduced, in the state of hybernation, to the level of he cold-blooded Reptile, the waste of its tissues diminishes to such an xtent, as to require but a very small exertion of the respiratory process o get rid of the carbonic acid, which is one of its chief products. And in hose animals which are capable of retaining their vitality when they are rozen, or when their tissues are completely dried up, vital activity and isintegration are alike entirely suspended, and consequently there is no arbonic acid to be set free.

537. But another source of Carbonic acid to be set free by the Respiraory process, and one which is peculiar to animals, consists in the rapid hanges which take place in the Muscular and Nervous tissues, in the ery act of performing their peculiar functions; the development of the Muscular and of the Nervous forces involving, as the very condition of heir production, a change in the substance of these tissues respectively; n which change a large quantity of Oxygen is consumed, and a large mount of Carbonic acid is generated. Hence in Man, as in all Animals n which the Nervo-Muscular apparatus constitutes the essential part of he organism, a powerful demand for Respiration is created by its activity; he amount of oxygen taken-in, and of carbonic acid exhaled, being determined, *cæteris paribus,* by the degree in which this apparatus is exercised.

538. Besides these sources of Carbonic acid which are common to all nimals, there is another which is restricted (or nearly so) to the two ighest classes, Birds and Mammals; these being distinguished by their ower of maintaining a constantly-elevated temperature. A part of this heat is generated by the oxygenation of the components of their disintegrating tissues, the metamorphosis of which takes place at a very rapid ate; but where this is not sufficient, their power of maintaining their emperature depends upon the *direct* combination of certain elements of he food with the oxygen of the air, by the combustive process.—The uantity of carbonic acid that is generated directly from the elements of he food, seems to vary considerably in different animals, and in different tates of the same individual. In the Carnivorous tribes, which spend he greater part of their time in a state of activity, it is probable that the uantity which is generated by the waste or metamorphosis of the tissues s sufficient for the maintenance of the required temperature; and that ittle or none of the carbonic acid set free in respiration is derived from he direct combustion of the materials of the food. But in Herbivorous nimals of comparatively inert habits, the amount of metamorphosis of

the tissues is far from being sufficient; and a large part of the food, consisting as it does of substances that cannot be applied to the nutrition of the tissues, is made to enter into direct combination with the oxygen of the air, and thus to compensate for the deficiency. In Man and other animals, which can sustain considerable variations of climate, and can adapt themselves to a great diversity of habits, the quantity of carbonic acid formed by the direct combination of the elements of the food with the oxygen of the air, will differ extremely under different circumstances (§ 402). It will serve as the *complement* of that which is formed in other ways; so that it will diminish with the increase, and will increase with the diminution, of muscular activity. It will also vary in an inverse ratio to the external temperature, increasing with its diminution (as more heat must then be generated), and diminishing with its increase; the effect of external heat being thus precisely opposite, in the warm-blooded animal, to that which it exerts on the cold-blooded (§ 536).—In all cases, if a sufficient supply of food be not furnished, the store of fat is drawn-upon; and if this be exhausted, the animal dies of cold (§ 416).

539. To recapitulate, then, the sources of Carbonic Acid in the animal body are threefold.—I. The continual decay of the tissues common to all organized bodies, which is favoured by all that promotes their vital activity, and retarded by every influence that depresses it.—II. The metamorphosis peculiar to the Nervous and Muscular tissues, which is the very condition of the production of their power, and which therefore bears a direct relation to the degree in which they are exerted.—III. The direct conversion of the carbon and hydrogen of the food into carbonic acid and water, which is peculiar to warm-blooded animals; and which varies in quantity, in accordance with the amount of heat to be generated.

Fig. 104.


Lung of *Triton cristatus*, magnified about 3 diam.;—*a*, pulmonary artery; *b*, pulmonary vein.

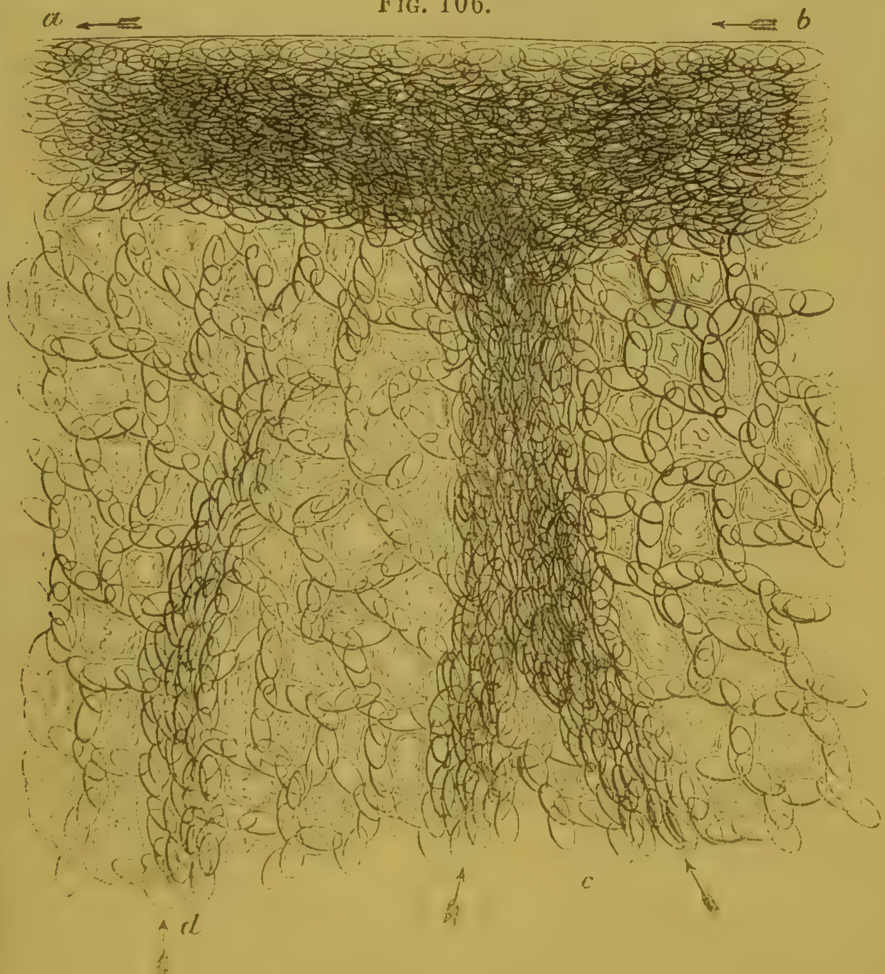
540. The wonderful nature of the structural arrangements which are made for the aeration of the blood in Man (as in Mammalia generally), and the completeness of the provisions whereby these are put into active operation, will be best understood, if, for the sake of contrast, we first bestow a brief survey on the Pulmonary apparatus of Reptiles; a class in which the demand for respiration is reduced to a comparatively low grade, by the absence of any necessity for the maintenance of an independent temperature; by the general torpor of their habits (whence arises a very small amount of 'waste' in the nervo-muscular apparatus), and by the very slow rate at which their organic functions are performed, and the life of the whole body is carried on.—The lungs of Reptiles are, for the most part, simple sacs; into which the bronchial tubes open freely, and on the walls of which the pulmonary vessels are distributed. The extent of surface is considerably increased, however, by the formation of a number of little pits or sacculi on the inner wall of the cavity, especially at its upper part; and between these we observe a sort of cartilaginous frame-work, which is continuous with the cartilage

f the bronchus on either side. Thus it happens ıat the network of pulmonary capillaries is exosed only on *one* side to the influence of the air. The general distribution of these vessels is shown ı the accompanying figures. It will be seen that ıe trunk of the pulmonary artery runs along one ide of the sac, and that of the pulmonary vein ong the other (Fig. 104); and that numerous ranches arise from the former, which subdivide ıto capillaries that ramify over the whole surce, and then reunite into small veins which rminate in the latter. The islets of parenchyma ft between the capillary vessels, are seen to be ıuch smaller than those which are usually to be bserved in the systemic circulation (Figs. 105, 06); so that the membrane is more copiously aversed by vessels, than almost any other that known. The walls of the capillaries, moreover, e much less distinct than those of the systemic rculation. These two conditions are obviously favourable to the exosure of the largest possible quantity of blood to the influence of the

FIG. 105.

Portion of the Lung of *Triton*, more highly magnified; the vessels, finely injected with size and vermilion, form a network so minute, that the parenchyma is only seen in small islets in its interstices.

FIG. 106.




Portion of the Lung of a living *Triton*, as seen under the microscope with the power of 150 diameters:—*a*, *b*, pulmonary vein, receiving blood from the large trunk *c*, and a smaller vessel *d*.

air; but as the surface is not an extensive one, the amount which can be thus exposed at any one time is very limited; and the pulmonary artery is often, in fact, like one of the smaller branches of the aorta, which trunk conveys a mixed fluid to the system at large.—The lungs of Reptiles are not, like those of Mammals, enclosed in a distinct cavity partitioned-off from the abdominal by the interposition of a diaphragm; but they lie in immediate contact with the other viscera: and the mechanism of inspiration and expiration is consequently far less complete, than it is in animals which possess a muscular diaphragm closing-in the floor of the thoracic cavity, and capable, by its contraction, of largely increasing the capacity of that cavity. In fact, many Reptiles are incapable of *drawing*-in air, and can only *force* it in by a process resembling deglutition.*

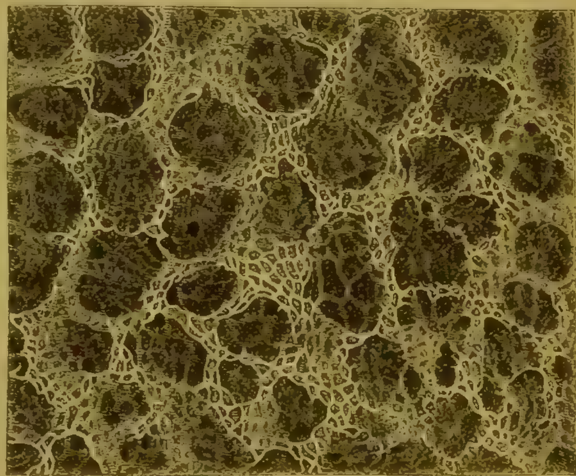
541. The size of the Lungs in Man and the Mammalia is far smaller in proportion to their bulk, than it is in most Reptiles; but this diminution is more than compensated by the minute subdivision of their cavities, by the peculiarity of the distribution of their blood-vessels, and by the arrangements whereby a continual and rapid interchange, both of the blood and of the air, is provided for.—The following are the points of most importance in the structure of the Human Lung.† The walls of the bronchial tubes contain distinct longitudinal and circular layers of fibrous structure; but the latter alone, according to Prof. Kölliker, contain muscular fibre-cells. These tubes divide and subdivide, like the branches of a tree, still retaining their ordinary characters, until they are no more than from 1-50th to 1-30th of an inch in diameter; and in these the longitudinal and annular fibres, together with the ciliated epithelium, come to an abrupt termination. Beyond this boundary, the tubular form of the air-passages continued from the bronchi is retained for some distance; but it is gradually changed by the irregular branching of the passages, and by the increase of the number of apertures in their walls, which lead to the air-vesicles. Thus, at last, each minute division of the air-passages becomes quite irregular in form; air-vesicles opening into every part of it, and almost constituting its walls; until it terminates, almost without dilatation, in an air-vesicle. This terminal portion of the air-passage, with its surrounding cluster of air-vesicles, may be regarded as forming a sort of lobule, and as representing the entire lung of a Frog or other Reptile; the whole lung of the Mammal being made up of a multitude of such lobules, which are almost exact repetitions of each other. Those vesicles which communicate directly with the bronchial tubes and intercellular passages, open into them by large circular apertures; and they are themselves similarly opened-into by other vesicles, which again communicate with others beyond them; so that each of the openings in the air-passage leads to a *series* of air-vesicles, extending from it to the surface of the lobule. The vesicles which communicate most directly with the air-passages, are more minute, and have a closer vascular network, than those which lie nearer the surface of the lobule; an arrangement which is in beautiful harmony with the relative facility of renovation of the air which they respectively

* See "Prin. of Phys., Gen. and Comp.," §§ 324*r*, 526, 527.

† See especially the Memoir by Mr. Rainey in the "Med.-Chirurg. Trans.," vol. xxviii.

contain. The air-vesicles have also lateral apertures into each other; so that all the parts of any one lobule freely communicate together. The walls of the air-vesicles are formed of a very thin and transparent membrane, which is folded sharply at the orifices of communication, so as to form a very definite border to them; and which is lined by an epithelial layer, composed of minute polygonal cells of from 1-1600th to 1-2250th of an inch in diameter, and from 1-2800th to 1-3800th of an inch in thickness (Kölliker). This lining membrane is distinctly fibrous; and its fibres are particularly strong and well-marked around the apertures of communication between the contiguous air-cells. These fibres have not any resemblance to muscular tissue; but rather correspond with those of yellow fibrous tissue.*—The diameter of the Human air-cells is about twenty times greater than that of the capillaries which are distributed upon their parietes; varying (according to the measurement of Weber) from the 1-200th to the 1-70th of an inch.† It has been calculated by M. Rochoux, that as many as 17,790 air-cells are grouped around each terminal bronchus; and that their total number amounts to no less than 600 *millions*. The capillary plexus is so disposed between the two layers which form the walls of two adjacent air-cells, as to expose one of its surfaces to each; by which provision the full influence of the air upon it is secured. The network of vessels is so close, that the diameter of the meshes is scarcely so great as that of the capillaries which enclose them; indeed it would be impossible to conceive of a method, by which blood, whilst still retained within vessels, should be spread over a larger surface for aeration. And if not restricted within vessels, it could not be ceaselessly and rapidly driven-on by the propulsive power of the heart, which acts no less efficiently upon the pulmonary circulation than upon the systemic, although the force exerted is much inferior, the resisting power being far less, in consequence of the shortness of the circuit.

Fig. 107.



Arrangement of the Capillaries of the air-cells of the *Human Lung*.

542. The fibrous coat of the bronchial tubes possesses a considerable amount of muscular contractility, which (according to the experiments of Dr. C. J. B. Williams)‡ may be excited by electrical, chemical, or

* It is suspected by Kölliker that there may be muscular fibre-cells among these, as he sees long nuclei in the walls of the air-vesicles. These, however, are neither so long nor so narrow as the proper nuclei of the fibre-cells (Fig. 79); and are just as probably the nuclei of capillary blood-vessels (Fig. 67).

† The dimensions given by Moleschott ("De Vesiculis Pulmonum Malpighianis") are very much less than these; the range of diameter being stated by him at between 1-120th and 1-1200th of an inch. The Author's own observations, however, lead him to regard Weber's statement as very near the truth; and that of Prof. Kölliker ("Mikroskopische Anatomie," band. ii. § 196) is almost precisely the same.

‡ "Report of the British Association for 1840," p. 411.

mechanical stimuli, applied to themselves; but this is not so readily excitable through their nerves, although the experiments of Volkmann* and Longet† have clearly shown the possibility of thus calling it into action. This contractility resembles that of the intestines or arteries, more than that of the voluntary muscles or heart; the contraction and relaxation being more gradual than that of the latter, though less tardy than that of the former. It is chiefly manifested in the smaller bronchial tubes, those of less than a line in diameter having been seen to contract gradually under the stimulus of galvanism, until their cavity was nearly obliterated; on the other hand, in the trachea and the larger bronchi, the cartilaginous rings prevent any decided diminution in the calibre of the tubes, and the muscular structure is much less distinct. It is remarked by Dr. Williams, that the contractility of the bronchial muscles is soon exhausted by the action of a stimulus; but that it may in some degree be restored by rest, even when the lung is removed from the body. When the stimulation is long continued, however, as by intense irritation of the mucous membrane during life, the contractile tissue passes into a state which resembles the tonic contraction of muscular fibre. The contractility is greatly affected by the mode of death, and is remarkably diminished by the action of vegetable narcotics, particularly stramonium and belladonna: whilst it seems to be scarcely at all affected by hydrocyanic acid. These facts are very important, as throwing light upon certain diseased conditions. It has long been suspected, that the dyspnœa of Spasmodic Asthma depends upon a constricted state of the smaller bronchial tubes, excited through the nervous system, frequently by a stimulating cause at some distance; and there can be now little doubt that such is the case. The peculiar influence of stramonium and belladonna, in diminishing the contractility of these fibres, harmonises remarkably with the well-known fact of the relief frequently afforded by them in this distressing malady.—It has been maintained by Dr. Radclyffe Hall,‡ that the contractility of the bronchial tubes is called into action in each expiratory movement, to assist in emptying the lungs. But no evidence has been adduced in support of this doctrine; and its improbability is apparent from the obvious fact, that a contraction of the air-tubes would impede, rather than promote, the emptying of the air-vesicles. It seems more probable that it serves to regulate the supply of air to the lobules, in accordance with the wants of the system, just as the contractility of the minute arteries regulates the supply of blood to the organs to which they proceed; and it may possibly be through this channel, that the remarkable variation is effected in the amount of respiration, which adapts the quantity of heat produced to the depression of the external temperature (§ 538). It has been further suggested by Dr. W. T. Gairdner,§ that the contractility of the smaller bronchi may serve to expel collections of mucus which have accumulated in them, and which neither ciliary action nor the ordinary expiratory efforts suffice to displace.

543. Although there is no sufficient reason to believe that the Lungs

* "Wagner's Handworterbuch," art. 'Nervenphysiologie,' § 586.
† "Anat. et Physiol. du Système Nerveux," tom. ii. p. 289.
‡ "Transactions of Provincial Medical Association," 1850.
§ "Edinburgh Monthly Journal," May, 1851.

are possessed of any power of vital contractility, yet their Elasticity prevents them from being altogether passive agents in the respiratory operation. The elastic tension is rapidly increased by the dilatation of the lungs with air; and the carefully conducted experiments of Dr. Hutchinson* lead him to estimate it at certainly not less than $\frac{1}{2}$lb upon each square inch of surface, when the lungs have been filled by the deepest possible inspiration; so that its whole amount (reckoning an average surface of 300 sq. in. for the male, and 247 sq. in. for the female) will be not less than 150lbs for the male, and 123$\frac{1}{2}$lbs for the female. This force is exerted in aid of the *ex*piratory movement, and is directly antagonistic to the *in*spiratory; so that the inspiratory muscles must overcome it, in order to produce complete distension of the pulmonary cavities. This distension is entirely accomplished by the action of the muscles external to the thorax, or partly forming its parietes. The lung completely fills the cavity of the pleura, in the healthy state at least; so that, when this is enlarged, a vacuum would be produced, if it were not occupied by a corresponding enlargement of the lung; and to effect this, the air rushes down the trachea, and thence passes into the entire substance of the lung, which it fills-out in every dimension. This distension is much more complete than any that could be occasioned by simple insufflation from the trachea; for long before the internal pressure could overcome the resistance set up by the elasticity of the lungs, and still more by that of the parietes of the chest (§ 545), to the full dilatation of the air-vesicles, the tissue of the lung itself would be almost certain to give way. This has actually happened in numerous instances; and it constitutes a very forcible objection to the use of any apparatus for artificial respiration, whose action is that of 'insufflation.'—The complete dependence of the expansion of the Lungs upon the enlargement of the cavity of the chest, is well shown by the effect of admission of air into the pleural cavity. When an aperture is made on either side, so that the air rushes-in at each inspiratory movement, the expansion of the lung on that side is diminished, or entirely prevented, in proportion to the size of the aperture. If air can enter through it more readily than through the trachea, an entire collapse of the lung takes place; and by making such an aperture on each side, complete asphyxia is produced. But if it be too small to admit the very ready passage of air, the vacuum produced by the inspiratory movement is more easily filled by the distension of the lungs, than by the rush of air into the pleural cavity; so that a sufficient amount of change takes place for the maintenance of life. This is frequently observed in the case of penetrating wounds of the thorax, in the surgical treatment of which, it is of great importance to close the aperture as completely as possible; when this has been accomplished, the air that had found its way into the cavity is soon absorbed, and the lung resumes its full play. Where one lung is obstructed by tubercular deposit, or is prevented in any other way from rightly discharging its function, an opening that freely admits air into the pleural cavity of the other side, is necessarily attended with an immediately fatal result; and in this manner it not unfrequently happens that chronic pulmonary diseases suddenly terminate in Asphyxia, a communication

* "Cyclopædia of Anatomy," art. 'Thorax,' vol. iv. p. 1058.

being opened by ulceration between a bronchial tube and the cavity of the thorax.

544. *Of the Respiratory Movements.*—The dilatation of the Pleural cavity during Inspiration, is chiefly accomplished by the contraction of the Diaphragm, which, from the high arch that it previously formed, becomes nearly plane; in this change of figure, it presses on the abdominal viscera, so as to cause them to protrude, which they are enabled to do by the relaxation of the abdominal muscles. In ordinary tranquil breathing (especially in children), the action of the diaphragm is alone nearly sufficient to produce the necessary exchange of air; but, when a full inspiration is required, the cavity of the chest is dilated laterally and antero-posteriorly, as well as inferiorly. The enlargement of the chest in both these directions is effected by the elevation of the ribs; for whilst, in the undilated state of the thorax, the ribs form an angle with their cartilages, which becomes less and less obtuse as we pass from the first rib downwards, the elevation of the ribs tends to bring them and their cartilages more nearly into a line, and thus separates them more widely from the median plane, and at the same time causes them to push forwards the sternum. Owing to the greater length of the lower true ribs, and the greater obliquity of their junction with their cartilages, both these changes are more considerable in the lower part of the thorax than in the upper; and this is especially the case in adult men, whose respiration has been designated as 'inferior costal,' whilst in females the mobility of the first rib and of the whole of the upper part of the thorax is greater, so that their respiration may be designated as 'superior costal.'—The thoracic muscles whose contraction participates in the ordinary movements of Inspiration, are (according to Dr. Hutchinson, Op. cit., p. 1055) the *external* intercostal, with those portions of the internal intercostals which pass between the cartilages, the levatores costarum, and a portion of the triangularis sterni, all of which have the same action, that of elevating the ribs. On the other hand, the thoracic Expiratory muscles are the proper costal portion of the *internal* intercostals, with the infracostales, and a part of the triangularis sterni. The expiratory movement will be assisted also by the abdominal muscles, which antagonize the diaphragm by pressing-back the abdominal viscera, and thus causing its ascent so soon as it has become relaxed. There are many accessory muscles, however, which take a share in violent respiratory movements, both inspiratory and expiratory. Thus all the muscles which elevate the scapula, may act through it upon the ribs, and the scaleni act directly upon the first rib; whilst all those which erect the spine, fix more perfectly the origins of these and other muscles which are to act upon the thorax. So, again, the expiratory movement is aided by the longissimus dorsi, sacro-lumbalis, and other muscles which tend to depress the ribs. In difficult respiration, almost every muscle in the body is made in some way subservient to the distension of the chest; thus, a patient suffering under urgent dyspnœa instinctively lays hold of some fixed object, so as to prevent his upper extremities from moving; and thus his scapula becomes a fixed point, from which the pectorales (major and minor) and serratus magnus can aid in elevating the ribs.

545. The relative amount of muscular force which is required for these two movements respectively, is affected in a very remarkable manner by

the elasticity of the walls of the thoracic cavity; for this (like the elasticity of the lungs) supplies a force which greatly aids the *ex*piratory movement, whilst it offers a corresponding opposition to the *in*spiratory. Here, also, the degree of force exerted increases very rapidly with the degree of distension. Thus in a body experimented-on by Dr. Hutchinson (Op. cit. p. 1056), the following were the relations between the amount of air forced-in, the resisting elasticity, as shown by the height of mercury supported, the actual pressure upon each square inch of surface which this indicated, and the total pressure over the surface of the chest, reckoning its area at 206 square inches :—

| | *Cubic inches.* | | *Pressure in height of Mercury.* | *Pressure per sq. in.* | *Total Pressure.* |
|---|---|---|---|---|---|
| Air forced in . | 70 | Resisting elasticity | 1·00 inch. | 7·8 oz. | 104·4 lbs. |
| „ | 90 | „ „ | 1·50 „ | 11·7 „ | 150·6 „ |
| „ | 180 | „ „ | 3·25 „ | 25·3 „ | 326·3 „ |
| „ | 200 | „ „ | 4·50 „ | 35·1 „ | 451·9 „ |

To this 451·9lbs. must be added at least 128lbs. for the elastic force of the lungs themselves at that degree of distension, making altogether 580lbs.; and as the subject of this observation could expire during life considerably more air than the highest amount forced into his chest after death, there can be little doubt (judging from the rapid ratio in which the elastic force increases when the distension is approaching its limits) that the muscular power required to overcome this, towards the close of a very deep inspiration, could not have been less than 1000lbs. The co-operation of the elastic resistance with the expiratory movement, and its antagonism to the inspiratory, is doubtless the principal cause why the power of the expiratory muscles, as tested by the height of the column of mercury supported by the air, should always be greater than that of the inspiratory muscles (see Dr. Hutchinson, Op. cit. p. 1061); and why the expiratory power should be very much greater when the chest has been well filled with air, than when it is comparatively empty. The following is given by Dr. Hutchinson as the range through which these powers may vary within the limits of health :—

| *Power of Inspiratory Muscles.* | | *Power of Expiratory Muscles.* |
|---|---|---|
| 1·5 inch. | Weak . . . . . . | 2·0 inches. |
| 2·0 „ | Ordinary . . . . . | 2·5 „ |
| 2·5 „ | Strong . . . . . . | 3·5 „ |
| 3·5 „ | Very strong . . . . | 4·5 „ |
| 4·5 „ | Remarkable . . . . . | 5.8 „ |
| 5·5 „ | Very remarkable . . . . | 7·0 „ |
| 6·0 „ | Extraordinary . . . . | 8·5 „ |
| 7·0 „ | Very extraordinary . . . | 10·0 „ |

ne expiratory power may be augmented by the habitual performance of ovements in which they participate; and thus the inspiratory power is e preferable test of the *vis vitæ*. This has been found by Dr. Hutchinn to bear some relation to height, being greatest (on an average of a nsiderable number of cases) when the stature is 5 feet 7 or 8 inches; d diminishing above that height, as well as below it.

546. It is impossible to form a correct estimate, by observations on e's-self, of the usual number and degree of the respiratory movements; ice the direction of the attention to them is certain to increase their

frequency and amount. In general it may be stated, that from 16 to 20 alternations usually occur in a minute;* of these, the ordinary inspirations involve but little movement of the thorax; but a greater exertion is made at about every fifth recurrence. The average numerical proportion of the respiratory movements to the pulsations of the heart, is about 1 : 5, 1 : 4½, or 1 : 4; and when this proportion is widely departed from, there is reason to suspect some obstruction to the aeration of the blood, or some disorder of the nervous system. Thus in Pneumonia, in which a greater or less amount of the lung is unfit for its office, the number of respirations increases in a more rapid proportion than the acceleration of the pulse; so that the ratio becomes as 1 to 3, or even 1 to 2, in accordance with the degree of engorgement.† In Hysterical patients, however, a similar increase, or even a greater one, may take place without any serious cause; thus Dr. Elliotson‡ mentions a case, in which the respiratory movements of a young female, through nervous affection, were 98 or even 106, whilst the pulse was 104. On the other hand, the respirations in certain typhoid conditions and in narcotic poisoning become abnormally slow, owing to the torpid condition of the nervous centres, the proportion being 1 to 6, or even 1 to 8; and in such cases, the lungs not unfrequently become œdematous, from a cause hereafter to be mentioned (§ 556).

547. Not only the rate of the Respiratory movements, but also their extent, is affected by various morbid conditions; thus when dislocation of the spine takes place above the origin of the intercostal nerves, but below that of the phrenic, so that the former are paralysed, the respiratory movement is confined to the diaphragm: and as this is insufficient, serum is effused into the lungs, and a slow Asphyxia supervenes, which usually proves fatal in from three to seven days. Even where the muscles and nerves are all capable of action, the full performance of the inspiratory movements is prevented, by the solidification or engorgement of any part of the lung, which interferes with its free distension; or by adhesions between the pleural surfaces, which offer a still more direct impediment. When these adhesions are of long standing, they are commonly stretched into bands, by the continual tension to which they are subjected. If the impeding cause affect both sides, the movements of both will be alike interfered with; but if one side only be affected, its movements will be diminished, whilst those of the other remain natural; and the physician hence frequently derives an indication of great value, in regard to the degree in which the lung is incapable of performing its functions. It is to be remembered, however, that the action both of the diaphragm and of the elevators of the ribs may be prevented, by pain either in the muscles themselves or in the parts which they move; thus the descent of the diaphragm is checked by inflammation of the abdominal viscera or of the peritoneum; and that of the intercostals by rheumatism, pleuritis, pericarditis, or other painful disorders of the parts forming the parietes of the thorax.

* See Dr. Hutchinson's Table, in "Cyclop. of Anat. and Phys.," vol. iv. p. 1085.

† See a Paper by Dr. Hooker, on the 'Relation between the Respiratory and Circulating Functions,' in the "Boston (N. E.) Medical and Surgical Journal;" an abstract of which will be found in the "British and Foreign Medical Review," vol. iv. p. 263.

‡ "Physiology," p. 215, note.

548. We have now to inquire into the mode in which the Muscular movements of Respiration are kept up by Nervous power.—There can be no doubt that these movements, though partly under the control of the Will, are essentially 'automatic' in their nature. Their chief centre is the upper part of the *Medulla Oblongata*, into which may be traced the principal *excitor* nerves that convey the stimulus on which the movements are dependent, whilst from it proceed the principal *motor* nerves by which they are carried into effect. And thus it happens that the whole of the Encephalon may be removed from above, and the Spinal cord (as far up as the origin of the phrenic nerve) from below, without suspending the most essential of the respiratory movements. But other parts of the automatic centres are concerned in the ordinary movements of respiration; and there is probably no part that may not be excited to action, by the extraordinary stimulus which results from a prolonged interruption to the aeration of the blood (§ 546). The chief 'excitor' of the respiratory movements is unquestionably the Pneumogastric nerve. When this is divided on both sides, according to the experiments of Dr. J. Reid,* the number of respiratory movements is considerably diminished, usually about one-half. Now if this nerve excites the motions of respiration by its powerful action in producing sensation, we should expect to find its trunk endowed with considerable sensibility, which is not the case; for all experimenters agree in stating that, when its trunk is pinched or pricked, the animal does not exhibit signs of pain nearly so acute, as when the trunks of the ordinary spinal nerves, or of the fifth pair, are subjected to similar treatment. It cannot be questioned, however, that its power as an excitor of respiration is very great; since, besides the fact of the diminution in the number of inspirations which occurs immediately on section of it, irritation of its trunk in the neck is instantly followed by an act of inspiration. It is evident that this power must arise from impressions made upon its peripheral extremities. The impression is probably due to the presence of venous blood in the capillaries of the lungs; or, as Dr. M. Hall thinks, to the presence of carbonic acid in the air-cells. Either or both may be true.—The Pneumogastric nerve, however, is *not* the *only* excitor of the respiratory movements; since, when the nerve is cut on each side, they still continue, though with less frequency. The removal of the Encephalon diminishes the frequency of the respiratory movements, whether it be performed before or after the section of the Vagi. Dr. Reid found that in a kitten of a day old, in which the inspirations had been 100 per minute, they fell to 40 when the Encephalon was removed; and on subsequently cutting the Pneumogastrics, the number of inspirations instantly fell to between 3 and 4 in the minute, and continued so for some time. Hence it has been supposed that the respiratory movements are partly dependent upon sensation, a motor influence being excited by it; but it may be fairly surmised, from the close dependence of nervous activity upon the oxygenation of the blood, that a 'besoin de respirer' may originate in the circulation of

* "Edinb. Med. and Surg. Journ.," vol. li.; and "Phys., Anat., and Pathol. Res.," p. 177.—Dr. Reid has satisfactorily shown the statement of many experimenters, that the inspirations are *increased* in frequency after this operation, to be erroneous; this idea having originated in their very prolonged and laborious character.

imperfectly aerated blood in the nervous centres themselves, and may become the direct excitor of respiratory movements.

549. But why (it may be asked) do the movements continue, when the Pneumogastrics have been divided, and the Encephalon has been removed? It is evident that there must be other excitors to the action of the respiratory muscles. Amongst these, the nerves distributed to the general surface, and particularly to the face, probably perform an important part; and in exciting the first inspiration, the Fifth pair seems the principal agent. It has long been a well-known fact, that the first inspiratory effort of the new-born infant is most vigorously performed, when the cool external air comes into contact with the face; and that impressions on the general surface, such as a slap of the hand on the nates, are often effectual in exciting the first inspiratory movements, when they would not otherwise commence. Dr. M. Hall relates an interesting case, in which the first inspiration was delayed, simply because the face was protected by the bed-clothes from the atmosphere;* and, on lifting up these, the infant immediately breathed. Dr. M. Hall has also mentioned the important fact, that although, if the cerebrum be removed, and the pneumogastrics divided, in a young kitten, the number of acts of respiration will be reduced to four in a minute, yet by directing a stream of air on the animal, or by irritating various parts of the general surface, we may excite twenty or thirty acts of respiration within the same space of time. He further remarks, that in the very young warm-blooded animal, as in the cold-blooded animal, the phenomena of the excito-motor power are far more vividly manifested, than in the older and warm-blooded. In the very young kitten, even when asphyxiated to insensibility, every touch, contact, or slight blow, every jar of the table, any sudden impression of the external air, or that of a few drops of cold water, induces at once energetic reflex movements, and acts of inspiration. This may be looked upon as Nature's provision for the first establishment of the acts of inspiration in the new-born animal.—But the influence of the nerves of the general system is by no means wanting in the adult; as many familiar facts demonstrate. Every one knows the fact, that the first plunge into cold water, the first descent of the streams of the shower-bath, or even the dashing of a glass of cold water in the face, will produce inspiratory efforts; and this fact has many important practical applications. Thus in the treatment of Asphyxia, whether congenital, or the result of narcotic poisoning, drowning, &c., the alternate application of cold and heat is found to be one of the most efficacious means of restoring the respiratory movements; and a paroxysm of hysteric laughter may be cut short by dashing a glass of cold water in the face. One of Dr. Reid's experiments strikingly demonstrates the variety of the provisions that have been made for the performance of this function. After dividing the pneumogastrics, and removing the cerebrum and cerebellum, he divided the spinal cord high up in the neck, so as to cut off the communication between the spinal nerves and the Medulla Oblongata; and he found that the frequency of the respiratory movements was still further diminished, although they were not even then entirely suspended; their continuance, after every channel of excitation appeared to have been cut

* "New Memoir on the True Spinal Marrow," &c., p. 29.

ff, being probably dependent (as Dr. Reid has suggested) on the circulaion of imperfectly aerated blood in the Medulla Oblongata.—It seems ot improbable that even the Sympathetic nerve, which derives many laments from the Cerebro-Spinal system, and which especially commuicates with the Pneumogastric nerves, may be one of the excitors to this unction; and this, perhaps, not only through its ramifications in the ungs, which are considerable, but also by its distribution on the systemic essels; so that it may convey to the Spinal Cord the impression of imerfectly-arterialized blood circulating through these, such as the Pneuogastric is believed to transmit from the lungs.

550. The Motor or 'efferent' nerves concerned in the function of espiration, are those which Sir C. Bell has grouped together in his respiratory system.' The most important of these, the Phrenic, arises om the upper part of the Spinal Cord; the Intercostals much lower own; whilst the Facial nerve and the Spinal Accessory, to the latter of hich, as will be shown hereafter (CHAP. XIV. Sect. 2), the motor powers f the Pneumogastric are chiefly due, take their origin in the Medulla blongata itself. But we must not decide upon the connection of a parcular nerve with a particular segment of the Spinal Cord, simply because diverges from it at that point; and the analogy of the Invertebrated asses favours the idea, that a direct structural connection exists between e ganglionic centre of the Respiratory movements, and the nerves which ansmit their influence to the muscles. Upon this point, however, it is nsafe to speculate; and we can only state it as a possibility, that some ich connection may be established in Vertebrated animals through the hite columns of the spinal cord.

551. That the Respiratory movements, as ordinarily performed, are sentially independent of the Will, appears not only from our own conciousness, but also from cases of paralysis; in some of which, the power the will over the muscles has been lost, whilst the movements have een kept up by the reflex action of the Medulla Oblongata or respiratory anglion; whilst in others, some of the respiratory muscles have been otionless during ordinary breathing, and yet have remained under the ower of the will.* That consciousness is not a necessary link in the ain of causes which produce the respiratory movements, we are enabled judge from the phenomena presented by the human being in sleep and ma, by anencephalous fœtuses, and by decapitated animals. This conusion is confirmed by a case recorded by Dr. H. Ley,† who had under s care a patient in whom the pneumogastrics appeared to be diseased; e lungs suffered in the usual way in consequence, and the patient had idently laborious breathing; but he distinctly said that he felt no easiness in his chest.—The experience of every one informs him, that the espiratory movements are partly under the control and direction of the ill, though frequently unrestrainable by it. In ordinary circumstances, hen the blood is being perfectly aerated, and there is a sufficient amount arterial blood in the system to carry on the functions of life for a short ne, we can suspend the respiratory actions during a few seconds without y inconvenience. If, however, we endeavour to prolong the suspension,

* Such cases are mentioned by Sir C. Bell, in the Appendix to his work on the Nervous stem.

† "On Laryngismus Stridulus," p. 417.

the stimulus conveyed by the excitor nerves to the Medulla Oblongata becomes too strong, and we cannot avoid making inspiratory efforts; and if the suspension be still further prolonged, the whole body becomes agitated by movements which are almost of a convulsive nature, and no effort of the will can then prevent the ingress of air.* It is easy to understand why, in the higher animals at least, and more especially in Man, the respiratory actions should be thus placed under the control of the will: since they are subservient to the production of those sounds, by which individuals communicate their feelings and desires to each other; and which, when articulate, are capable of so completely expressing what is passing in the mind of the speaker. If the respiratory muscles of Man were no more under his control, than they appear to be in the Insect or Molluscous animal, he might be provided with the most perfect apparatus of speech, and yet he would not be able to employ it to any advantage.

552. The motor power of the Respiratory nerves is exercised, however, not only on the muscles which perform the inspiratory and expiratory movements, but on those which guard the entrance to the wind-pipe, and also on certain other parts. The movements of the internal respiratory apparatus are chiefly, if not entirely, effected through the medium of the motor fibres, which the Pneumogastric contains. These motor fibres exist in very different proportions in its different branches. For example, the pharyngeal and œsophageal branches, by which the muscles of deglutition are excited to contraction (§§ 427, 428), possess a much larger amount of them, and exhibit much less sensibility when irritated, than do other divisions of the trunk. Between the superior and inferior laryngeal nerves, again, there is an important difference, which anatomical and experimental research has now very clearly demonstrated. It has long been known, that section of the Pneumogastrics in the neck, above the inferior laryngeals, is frequently followed by suffocation, resulting from closure of the glottis; and hence it has been inferred, that the office of the inferior laryngeals was to call into action the dilators of the larynx, whilst the superior laryngeals were supposed to stimulate the constrictors. This view, however, is incorrect. It is inconsistent with the results of anatomical examination into the respective distribution of these two trunks; and it has been completely overthrown by the very careful and satisfactory observations and experiments of Dr. J. Reid,† which have established that, whilst the *inferior* laryngeal is the *motor* nerve of nearly all the laryngeal muscles, the *superior* laryngeal is the *excitor* or *afferent* nerve, conveying to the Medulla Oblongata the impressions by which muscular movements are excited. Its motor endowments are limited to

* It is asserted by M. Bourdon ("Recherches sur le Mécanisme de la Respiration," p. 21), that no person ever committed suicide, though many have attempted to do so, by simply holding the breath; the control of the will over the respiratory muscles not being sufficiently great, to antagonise the stimulus of the "besoin de respirer," when this has become aggravated by the temporary cessation of the action. But such persons have succeeded better, by holding the face beneath the surface of water; because here another set of muscles is called into action, which are much more under the control of the will, than are those of respiration; and a strong volition applied to these can prevent all access of air to the lungs, however violent may be the inspiratory efforts.

† "Edinb. Med. and Surg. Journ.," Jan. 1838; and "Anat., Physiol. and Pathol. Res.," chap. iv.

ıe crico-thyroid muscle, to which alone of all the muscles its filaments .n be traced, the remainder being distributed beneath the mucous rface of the larynx; and its sensibility is very evident, when it is nched or irritated during experiments upon it. On the other hand, .e motor character of the inferior laryngeal branch is shown by its very ıght sensibility to injury, its nearly exclusive distribution to muscles, ıd its influence in exciting contraction of these when its separated trunk stimulated.

553. It has been ascertained by Dr. J. Reid, that, if the inferior laryngeal ranches be divided, or the trunk of the pneumogastric be cut above their igin from it, there is no constriction of the glottis, but a paralysed state its muscles. After the first paroxysm occasioned by the operation, a eriod of quiescence and freedom from dyspnœa often supervenes, the spirations being performed with ease so long as the animal remains at st; but an unusual respiratory movement, such as takes place at the ommencement of a struggle, induces immediate symptoms of suffocation, –the current of air carrying inwards the arytenoid cartilages, which are endered passive by the paralysed state of their muscles; and these, fall-ıg upon the opening of the glottis, like valves, obstruct the entrance of r into the lungs. The more effort is made, the greater will be the bstruction: and accordingly, it is generally necessary to counteract the endency to suffocation, when it is desired to prolong the life of the animal ter this operation, by making an opening into the trachea. Dr. Reid urther ascertained, that the application of a stimulus to the inferior ryngeal nerves, when separated from the trunk, would occasion distinct uscular contractions in the larynx; whilst a corresponding stimulus pplied to the superior laryngeal occasioned no muscular movement, xcept in the crico-thyroid muscle. But when the superior laryngeals ere entire, irritation of the mucous surface of the larynx, or of the runks themselves, produced contraction of the glottis and efforts to ough; effects which were at once prevented by dividing those nerves, nd thereby cutting off their communication with the Medulla Oblongata. here can be no doubt, then, that the superior and inferior laryngeal ranches constitute the circle of incident and motor nerves, by which the perture of the glottis is governed, and by which any irritation of the rynx is made to close the passage, so as to prevent the entrance of nproper substances; whilst the superior laryngeal nerve also excites the uscles of expiration, so as to cause the violent ejection of a blast of air, y which the offending gas, fluid, or solid, may be carried off. The effect f carbonic acid in causing spasmodic closure of the glottis is well known; nd affords a beautiful example of the protective office of this system f nerves. The mucous surface of the trachea and bronchi appears from ıe experiments of Valentin, to be endowed with excitability, so that imuli applied to it produce expiratory movements; and this evidently perates through the branches of the pneumogastric distributed upon the ıembrane. Here, as elsewhere, we find that a stimulus applied to the *urface* has a much more decided influence, than irritation of the *trunk* of ıe nerve supplying it.

554. The actions of *sighing*, *yawning*, *sobbing*, *laughing*, *coughing*, and *ıeezing*, are nothing else than simple modifications of the ordinary move-ıents of respiration, excited either by mental emotions, or by some

stimulus originating in the respiratory organs themselves.—*Sighing* is nothing more than a very long-drawn inspiration, in which a larger quantity of air than usual is made to enter the lungs. This is continually taking place to a moderate degree; and we notice it particularly when the attention is released, after having been fixed upon an object which has excited it strongly, and which has prevented our feeling the insufficiency of the ordinary movements of respiration. Hence this action is only occasionally connected with mental emotion.—*Yawning* is a still deeper inspiration, which is accompanied by a kind of spasmodic contraction of the muscles of the jaw, and also by a very great elevation of the ribs, in which the scapulæ partake. The purely involuntary character of this movement is sometimes seen, in a remarkable manner, in cases of palsy; in which the patient cannot raise his shoulder by an effort of the will, but does so in the act of yawning. Nevertheless this act may be performed by the will, though not completely; and it is one that is particularly excited by an involuntary tendency to imitation, as every one must have experienced who has ever been in company with a set of yawners.—*Sobbing* is the consequence of a series of short convulsive contractions of the diaphragm; and it is usually accompanied by a closure of the glottis, so that no air really enters.—In *Hiccup*, the same convulsive respiratory movement occurs, and the glottis closes suddenly in the midst of it; the sound is occasioned by the impulse of the column of air in motion against the glottis.—In *Laughing*, a precisely reverse action takes place; the muscles of expiration are in convulsive movement, more or less violent, and send out the breath in a series of jerks, the glottis being open. This sometimes goes on, until the diaphragm is more arched, and the chest is more completely emptied of air, than it could be by an ordinary movement of expiration.—The act of *Crying*, though occasioned by a contrary emotion, is, so far as the respiration is concerned, very nearly the same as the last. Every one knows the effect of mixed emotions, in producing an expression of them which is "between a laugh and a cry."—The greater part of the preceding movements seem to belong as much to the *consensual* or to the *emotional*, as to the purely *reflex* group of actions; for whilst they are sometimes the result of peculiar states of the respiratory organs, or of the bodily system in general, they may also be called forth by influences, which operate directly through the senses, or which excite the emotions. Thus, whilst Sighing and Yawning often occur as simple results of deficient aeration, they may be brought on,—the former by a depressed state of the feelings,—the latter by the mere sight of the act in another person. The actions of Laughter and Crying seem never to originate in the respiratory system; but to be always either expressions of the emotions, or simple results of sensations,—as when crying arises from the sense of pain,—and laughter from that of tickling. The origin of the act of Hiccup does not seem very clear; but the movement is probably of a purely reflex nature.

555. The purposes of the acts of Coughing and Sneezing are, in both instances, to expel substances from the air-passages, which are sources of irritation there; and this is accomplished in both, by a violent expiratory effort, which sends forth a blast of air from the lungs.—*Coughing* occurs, when the source of irritation is situated at the back of the mouth, in the trachea, or bronchial tubes. The irritation may be produced by acrid

ıpours, or by liquids or solids, that have found their way into these ıssages; or by secretions which have been poured into them in unusual ıantity, as the result of disease; or by the simple entrance of air specially if cold), when the membrane is in a peculiarly irritable state. ny of these causes may produce an impression upon the excitor fibres of .e Pneumogastrics, which, being conveyed to the Medulla Oblongata, ves rise to the transmission of motor impulses to the several muscles, ..at combines them in the act of coughing. This act consists,—1st, a long inspiration, which fills the lungs; 2nd, in the closure of .e glottis at the moment when expiration commences; and 3rd, in the ırsting open (as it were) of the glottis, by the violence of the expiratory ovement; so that a sudden blast of air is forced up the air-passages, rrying before it anything that may offer an obstruction.—The difference ·tween Coughing and *Sneezing* consists in this,—that in the latter, the mmunication between the larynx and the mouth is partly or entirely ›sed by the drawing-together of the sides of the velum palati over the .ck of the tongue; so that the blast of air is directed, more or less com- etely, through the nose, in such a way as to carry off any source of ·itation that may be present there.—It is difficult to say how far these tions are simply reflex; or how far they may require the stimulus of ›nsation for their performance.

556. Various alterations are produced in the Lungs, by section of the ıeumogastric nerves; and it has been supposed that these exert some ore immediate and direct influence over the condition of those organs, an their connection with the respiratory movements will serve to count for. The inquiry into the nature and succession of these changes s been most carefully prosecuted by Dr. J. Reid (Op. cit.); and as his sults have a very important bearing on several physiological and patho- gical questions of great interest, a summary of them will be here given. In the first place, it has been fully established by Dr. Reid, that section the Vagus on one side only does not necessarily, or even generally, duce disease of that lung; and hence the important inference may be awn, that the nerve does not exercise any *immediate* influence on its nctions. When both Vagi are divided, however, the animal rarely sur- ves long; but its death frequently results from the disorder of the gestive functions. Nevertheless, the power of digestion is sometimes stored sufficiently to re-invigorate the animals; and their lives may then prolonged for a considerable time (§ 446). In fifteen out of seventeen imals experimented-on by Dr. Reid, the lungs were found more or less fit for the healthy performance of their functions. The most common orbid changes were a congested state of the blood-vessels, and an effusion frothy serum into the air-cells and bronchial tubes. In eight out of fifteen, these changes were strongly marked. In some portions of the ıgs, the quantity of blood was so great as to render them dense. The gree of congestion varied in different parts of the same lung; but it was ıerally greatest at the most depending portions. The condensation was ıerally greater than could be accounted-for by the mere congestion of od in the vessels, and probably arose from the escape of the solid ts of the blood into the tissue of the lung. In some instances the ıdensation was so great, that considerable portions of the lung sank in ter, and did not crepitate; but they did not present the granulated

appearance of the second stage of ordinary pneumonia. In five cases in which the animals had survived a considerable time, portions of the lungs exhibited the second, and even the third stages of pneumonia, with puriform effusion into the small bronchial tubes; and in two, gangrene had supervened.—One of the most important points to ascertain in an investigation of this kind, is the first departure from a healthy state; to decide whether the effusion of frothy reddish serum, by interfering with the usual change in the lungs, *causes* the congested state of the pulmonary vessels and the laboured respiration; or whether the effusion is the *effect* of a previously-congested state of the blood-vessels. The former is the opinion of many physiologists, who have represented the effusion of serum as a process of morbid secretion, directly resulting from the disorder of that function produced by the section of the nerve; the latter appears the unavoidable inference from the carefully-noted results of Dr. Reid's experiments. In several of these, only a very small quantity of frothy serum was found in the air-tubes, even when the lungs were found loaded with blood, and when the respiration before death was very laboured. This naturally leads us to doubt, whether the frothy serum is the cause of the laboured respiration, and of the congested state of the pulmonary vessels, in those cases where it is present; though there can be no doubt that, when once it is effused, it must powerfully tend to increase the difficulty of respiration, and still further to impede the circulation through the lungs. Dr. R. has satisfied himself of an important point which has been overlooked by others, namely, that this frothy fluid is not mucus, though occasionally mixed with it, but that it is the frothy serum so frequently found in cases where the circulation through the lungs has been impeded before death. From this and other facts, Dr. R. concludes "that the congestion of the blood-vessels is the first departure from the healthy state of the lung, and that the effusion of frothy serum is a subsequent effect."—The next point, therefore, to be inquired into, is the cause of this congestion; and this is most satisfactorily explained, in accordance with the general laws of the Circulation (§ 527), by remembering that section of the Pneumogastrics greatly diminishes the frequency of the respiratory movements, and that the quantity of air introduced into the lungs is, therefore, very insufficient for the due aeration of the blood. There is now abundant evidence, in regard to the Pulmonary circulation in particular, that, to prevent the admission of oxygen in the lungs, either by causing the animal to breathe pure nitrogen or hydrogen, or by occlusion of the air-passages, is to bring the circulation through their capillaries to a speedy check (§ 575). Hence we should at once be led to infer, that diminution in the number of Respiratory movements would produce the same effect; and as little or no difference in their frequency is produced by section of one Vagus only, the usual absence of morbid changes in the lung supplied by it is fully accounted-for. The congestion of the vessels induced by insufficient aeration, satisfactorily accounts not only for the effusion of serum, but also for the tendency to pass into the inflammatory condition, sometimes presented by the lungs, as by other organs similarly affected. Dr. Reid confirms this view, by the particulars of cases of disease in the human subject, in which the lungs presented after death a condition similar to that observed in the lower animals after section of the Vagi; and in these individuals, the respiratory movements

ıd been much less frequent than natural during the latter part of life, ving to a torpid condition of the nervous centres. The opinion (held pecially by Dr. Wilson Philip) that section of the Par Vagum produces ıe serous effusion, by its direct influence on the function of Secretion, is ırther invalidated by the fact stated by Dr. Reid, that he always found ıe bronchial membrane covered with its true mucus, except when inammation was present.—"The experimental history of the Par Vagum," is justly remarked by Dr. Reid, "furnishes an excellent illustration of ıe numerous difficulties with which the physiologist has to contend, om the impossibility of insulating any individual organ from its mutual tions and reactions, when he wishes to examine the order and depenence of its phenomena." In such investigations, no useful inference can drawn from one or two experiments only; in order to avoid all sources fallacy, a large number must be made; the points in which all agree ust be separated from others in which there is a variation of results; ıd it must be then inquired, to what the latter is due.*

## 2. *Effects of Respiration on the Air.*

557. The total amount of air which can be drawn into the Lungs by ıe deepest possible inspiratory movement, by no means affords a measure the quantity which they ordinarily contain. It is in fact composed, as as first pointed out by Mr. Julius Jeffreys,† of several different quanties, which may be distinguished as follows:—

1. *Residual Air;* that which cannot be displaced by the most powerful piration, which always remains in the thorax so long as the lungs retain ıeir natural structure, and over which, therefore, we have no control.

2. *Supplemental Air;* that portion which remains in the chest after .e ordinary gentle expiration, but which may be displaced at will.

3. *Breathing* or *Tidal Air;* that volume which is displaced by the nstant gentle inspiration and expiration.

4. *Complemental Air;* the quantity which can be inhaled by the epest possible inspiration, over and above that which is introduced in dinary breathing.

he amount which can be expelled by the most forcible expiration after ıe fullest inspiration, and which is consequently the sum of the 2nd, 3rd, ıd 4th of these quantities, is designated by Dr. Hutchinson‡ as the *ital Capacity*, being that volume of air which can be displaced by *living ovements.* This 'vital capacity' is less dependent than might have been ıpposed, upon the absolute *dimensions* of the thoracic cavity, being yet ore influenced by its *mobility.* Thus of two sets of men of the same ight, one measuring 35 inches around the chest, and the other 38

* On the important subject of the Mechanism of Respiration, the following Memoirs may consulted in addition to those already referred to:—Dr. J. Reid's Art. 'Respiration' in Cyclop. of Anat. and Physiol.;" Dr. Hutchinson in "Med.-Chir. Trans.," vol. xxix.; Dr. bson in "Phil. Trans.," 1846, "Med. Gaz.," vol. xli., "Med.-Chir. Trans.," vol. xxxi., d "Trans. of Prov. Med. Assoc.," 1850; Beau and Maissiat in "Archiv. Gén.," 1842; endelssohn "Der Mechanismus der Respiration und Circulation," Berlin, 1845; and mon "Ueber die menge der ausgeathmeten Luft bey verscheidenen Menschen," Giessen, 48.

† "Statics of the Human Chest," 1843.

‡ "Cyclop. of Anat. and Physiol.," Art. 'Thorax.'

inches, the average vital capacity of the first was found to be 235 inches, and that of the second only 226 inches; for notwithstanding the greater absolute capacity indicated by the larger circumference of the latter, the inferior mobility of their chests caused more 'residual air' to remain behind after the deepest expiration. By taking the average of nearly 5000 observations, Dr. Hutchinson has arrived at the very remarkable conclusion (Op. cit., p. 1072), that of all the elements whose variation might be supposed to affect the 'vital capacity,' *Height* alone seems to have any constant relation to it; and that this relation is capable of being expressed in a simple numerical form. The following table represents the 'vital capacity' regarded by Dr. H. as necessary to health at the middle period of life, in the Male sex, for each inch of height between five and six feet:—

| *Height.* | *Vital Capacity.* |
|---|---|
| 5 ft. 0 in. to 5 ft. 1 in. | 174 cubic in. |
| 5 „ 1 „ 5 „ 2 „ | 182 „ |
| 5 „ 2 „ 5 „ 3 „ | 190 „ |
| 5 „ 3 „ 5 „ 4 „ | 198 „ |
| 5 „ 4 „ 5 „ 5 „ | 206 „ |
| 5 „ 5 „ 5 „ 6 „ | 214 „ |
| 5 „ 6 „ 5 „ 7 „ | 222 „ |
| 5 „ 7 „ 5 „ 8 „ | 230 „ |
| 5 „ 8 „ 5 „ 9 „ | 238 „ |
| 5 „ 9 „ 5 „ 10 „ | 246 „ |
| 5 „ 10 „ 5 „ 11 „ | 254 „ |
| 5 „ 11 „ 6 „ 0 „ | 262 „ |

This relation may be briefly expressed by the rule, that *for every inch of stature, from five to six feet, eight additional cubic inches of air* (at 60° Fahr.) *are given out by a forced expiration after a full inspiration.*—There is also a relation between 'vital capacity' and *Weight;* but of a different kind from that which might have been anticipated. So far as the increase in weight is simply proportional to the increase in height, the relation is of course the same for the one as for the other. But if the excess of weight should depend upon corpulence, the vital capacity *decreases* in a very marked manner, being always very low in corpulent men. The general result of Dr. Hutchinson's observations on this point is expressed by him as follows: When the man exceeds the average weight (at each height) by 7 per cent, *the vital capacity decreases* 1 *cub. in. per lb. for the next* 35 *lbs. above this weight.*—The influence of *Age* upon the 'vital capacity' is less marked than might have been anticipated. The general fact seems to be, that the 'vital capacity' undergoes a slight increase between 15 to 35 years, and then gradually decreases, the decline being more rapid than the augmentation, so that by the age of 66 it has diminished to about 4-5ths of the maximum.—There does not seem to be as close a relation between the 'vital capacity' and *Muscular Vigour*, as might *a priori* have been expected, and as an attempt has been made to establish.* Cases are not unfrequent in which men of athletic constitution have an absolute deficiency, whilst others by no means remarkable for physical power present a large excess.† In fact, as Dr. R. Hall has justly remarked, this measure indicates, not what a person *does* breathe, but what he *can*

* See Dr. Jackson in "American Medical Examiner," 1851, p. 51.

† See Dr. Radclyffe Hall in "Trans. of Prov. Med. and Surg. Assoc.," 1851.

breathe.—The *maximum* 'vital capacity' met with by Dr. Hutchinson in his entire series of observations, was 464 cub. in.; this was in a man 7 feet high, whose weight was 308 lbs. The *minimum* was only 46 cub. in.; this was in a dwarf (Don Francisco) whose height was only 29 inches, and weight 40 lbs.

558. But however constant the above averages may prove to be, when tested by a still larger number of observations, it yet remains to be determined within what limits individual variation may range, without departure from the standard of health. It is considered by Dr. Hutchinson (Op. cit. p. 1079) that a deficiency of 16 per cent (unless the individual should be very corpulent) should excite suspicion of disease; but the observations of Dr. C. R. Hall (loc. cit.) seem to show that the range is considerably wider, especially in females. They also indicate that even a marked deficiency in vital capacity must not be regarded as indicative of pulmonary disease; for it may be dependent upon disorder of the abdominal viscera, especially upon congested liver.

559. In estimating, however, the effects of the Respiratory function upon the air which passes through the lungs, we are not so much concerned with the quantity which *may* be drawn-in and forced-out, as with that actually exchanged at each movement. There are many difficulties in arriving at any exact conclusion upon this point; and hence it happens that the estimates of those who have inquired into it are singularly discrepant. The following are the amounts assigned by some of the most recent experimenters.

| | | | |
|---|---|---|---|
| Herbst * | | 20—30 | cubic inches. |
| Valentin † | | 14—92 | " |
| Vierordt ‡ | | 10—42 | " |
| Coathupe § | | 16 | " |
| Hutchinson ‖ | average | 16—20 | " |
| | extremes | 7—77 | " |

If we take 20 cubic inches as the average quantity exchanged at each respiration, we cannot but observe how small a proportion it bears to the entire amount which the lungs usually contain; for the 'residual volume,' which cannot be expelled, is estimated by Dr. Hutchinson at from 75 to 100 cubic inches, and the 'reserve volume,' which can only be expelled by a forced expiration, is about as much more; the sum of the two being from 150 to 200 cub. in., or from $7\frac{1}{2}$ to 10 times the 'breathing volume.' Now it is obvious that if no provision existed for mingling the air inspired with the air already occupying the lungs, the former would penetrate no further than the larger air-passages; and as this would be again thrown out at the next expiration, the bulk of the air contained in the lungs would remain altogether without renewal, and the expired air would not be found to have undergone any change.¶ That a change *is* effected, however, in the whole volume of the air contained in the lungs, with every inspiration, is indicated by the difference between the inspired and

* "Meckel's Archiv.," 1828.
† "Lehrbuch der Physiologie," band i. p. 538.
‡ "Wagner's Handwörterbuch," band ii. p. 835.
§ "Philosophical Magazine," 1839, vol. xiv. p. 401.
‖ "Cyclop. of Anat. and Phys.," vol. iv. p. 1067.
¶ See Mr. Jeffreys's "Statics of the Human Chest," in which this important point first received due consideration.

expired air; and this change must be attributed to the 'mutual diffusion' of gases, these (as discovered by Prof. Graham) tending to interpenetrate one another, when of different densities or of different temperatures.

560. The total amount of air which passes through the Lungs in twenty-four hours, will of course vary with the extent and frequency of the respiratory movements; and these are liable to be affected by many circumstances, but particularly by the relative degrees of repose and of exertion. Moreover, as any such computation must be based upon the datum of the ordinary volume of breathing or 'tidal' air, it is obvious that the estimates of different observers must vary with the amount they adopt. Thus Mr. Coathupe's estimate of the diurnal total is 460,800 cub. in., or 366⅓ cubic feet; that of Vierordt, from his observations on his own person in a state of rest, is 530,026 cub. in., or 306⅔ cub. feet, but this, when corrected (by Scharling's experiments) for a moderate amount of exertion, would be raised to 624,087 cub. in., or 361 cub. feet; and that of Valentin is as high as 688,348 cub. in., or 398½ cub. feet.—It is of great practical importance to determine the quantity of air which ought to be allowed for consumption by individuals confined in prisons, workhouses, schools, &c.; and for this, experience seems to have fixed 800 cubic feet as the *minimum* that can be safely assigned, except where extraordinary provisions are in operation for its constant renewal by ventilation. The evil consequences of an insufficient supply of air will be noticed hereafter (Sect. 3).

561. The alterations in this air which are effected by Respiration, mainly consist in the removal of a portion of its *Oxygen*, and the substitution of a quantity of *Carbonic acid*, usually rather less in bulk than the oxygen which has disappeared. The proportion of the air thus changed appears to vary according to the frequency of the respirations. Thus Vierordt* found that, if he only respired *six* times in a minute, the quantity of Carbonic acid was 5·5 per cent of the whole air exhaled; with *twelve* respirations, it was 4·2; with *twenty-four*, it was 3·3; with *forty-eight*, it was 3·0; and with *ninety-six* it was 2·6 per cent. In some of the experiments of Messrs. Allen and Pepys, it was as much as 8 per cent. Probably about 4·35 per cent may be taken as the average, at the ordinary rate of respiration.—It appears, however, from the researches of the last-named experimenters, that, if the air be already charged in some degree with Carbonic acid, the quantity exhaled is much less; for, when 300 cubic inches of air were respired for *three minutes*, only 28½ cubic inches (9½ per cent) of carbonic acid were found in it; although the previous rate of its production, when fresh air was taken-in at every respiration, was 32 cubic inches in a minute. Knowing, then, the necessity of a free excretion of carbonic acid, we are led by this fact to perceive the high importance of ventilation; for it is not sufficient for health, that a room should contain the quantity of air requisite for the support of its inhabitants during a given time; since after they have remained in it but a part of that time, the quantity of carbonic acid which its atmosphere will contain, will be large enough to interfere greatly with the due aeration of their blood, and will thus cause oppression of the brain, and the other morbid affections that result from the accumulation of carbonic

* "Physiologie des Athmens," pp. 102–149.

acid in the circulating fluid.—It appears from the experiments of Dr. Snow, that the presence of Carbonic acid in the atmosphere acts more deleteriously upon the system, in proportion as the normal quantity of Oxygen has been reduced. He found that birds and mammalia, introduced into an atmosphere containing only from 10½ to 16 per cent of oxygen, soon died, although means were taken to remove the carbonic acid set free by their respiration, as fast as it was formed; whilst, on the other hand, an increase in the proportion of carbonic acid to 12 or even 20 per cent—the per-centage of oxygen being kept to its regular standard of 21 per cent—did not appear to enfeeble the vital actions more rapidly than did the reduction of the oxygen in the experiments just referred to. Dr. Snow concludes, from his experiments on the lower animals, that 5 or 6 per cent of carbonic acid cannot exist in an atmosphere respired by Man, without danger to life; and that less than half this amount will soon be fatal, when it is formed at the expense of the oxygen of the air.*

562. The reaction which thus takes place between the Air and the Blood, is partly explicable upon physical principles. If the Blood come to the lungs charged with Carbonic acid, and be exposed in their cells to the influence of atmospheric air, which is a mixture of Oxygen and Nitrogen, an endosmose and exosmose of gases will take place.† The carbonic acid of the blood will pass out, to be replaced by oxygen and nitrogen; and the quantity of the former which enters will be much greater than that of the latter, on account of the superior facility with which oxygen passes through porous membranes. If the venous blood also contain nitrogen as well as carbonic acid, this also will pass out, to be replaced by the oxygen of the air. Thus, there will be a continual exosmose of carbonic acid and nitrogen, and a continual endosmose of oxygen and nitrogen.—The exhalation and absorption of Nitrogen appear usually to balance each other, so that the amount of this gas in the respired air undergoes little change; a slight increase in the Nitrogen of the expired air being the alteration most constantly noticed. But the case is different in regard to the exchange of Carbonic acid and Oxygen. According to the law of 'mutual diffusion' of gases, the volume of Oxygen that is taken in, should exceed that of the Carbonic acid which passes out, in the proportion of 1174 to 1000; and it has been attempted by Valentin and Brunner‡ to show, that, if a reasonable allowance be made for accidental causes of disturbance, this is the actual proportion between the Oxygen absorbed and the Carbonic acid given out, as indicated by experiment. Such, however, cannot be the case, since the departures are too wide to be accounted for on this hypothesis. Still there appears to the Author no adequate reason for doubting that the process of exchange is mainly effected by the force of 'mutual diffusion;' the result of its action, however, being determined by a great number of modifying conditions; so that the formula which

* "Edinb. Med. and Surg. Journal," 1846.

† See "Princ. of Phys., Gen. and Comp.," § 495.—It has been recently affirmed by Dr. Bence Jones ("Medical Times," 1851, p. 169), that the law of the 'diffusion of gases' does not apply to the respiration of air-breathing animals; since a gas is on one side of the septum and a liquid on the other. But it was long since shown by Dr. Mitchell of Philadelphia, that the tendency to mutual diffusion and replacement exists between atmospheric air and gases dissolved in water; and that this is not prevented by the interposition of a permeable membrane.

‡ Valentin's "Lehrbuch der Physiologie," band i. pp. 507–580.

expresses the law of its action in those simplest cases, in which the result is determined solely by the tendency to mutual penetration between gases on the opposite sides of a porous septum that affords them free passage, can scarcely hold good when the septum is a moist animal membrane, through which these gases pass with very different degrees of facility, and when one side of it is in contact with a liquid, through which they are diffusible with different degrees of readiness.

563. The recent experiments of MM. Regnault and Reiset* appear to have furnished the solution of the wide differences in the estimates which various experimenters have given, as to the relative amount of Oxygen absorbed and of Carbonic acid exhaled; by showing that it depends,—not, as Dulong and Despretz supposed, upon the ordinary regimen of the animal (the proportion of oxygen absorbed being much larger in Carnivora than in Herbivora), — but upon the nature of the aliment on which the animal is fed at the time of the experiment. Animals fed on flesh absorb much more oxygen in proportion, than those fed on a vegetable diet; thus in a dog exclusively nourished on flesh, the proportion of oxygen absorbed, to 100 parts of carbonic acid exhaled, was 134·3, or much *above* that which the law of mutual diffusion would indicate; whilst in a rabbit fed exclusively upon vegetable food, the proportion of oxygen absorbed was only 109·34 to 100 parts of carbonic acid exhaled, or *less* than the calculated amount. The difference between the relative proportions of surplus Oxygen, in the same animal, under opposite circumstances, was found to be as much as 62 : 104. These experimenters further ascertained that, when an animal is kept fasting, the relation between the Oxygen absorbed and the Carbonic acid exhaled is nearly the same as when the animal is fed on flesh; the reason apparently being, that in the former case the animal's respiration is kept up at the expense of the constituents of its own body, which correspond with animal food in their composition. There can be no doubt that, on the whole, a considerable surplus of oxygen is absorbed into the system; and it appears probable that a part of this additional oxygen is made to combine with hydrogen furnished by the food or by the disintegration of the tissues, the water thus generated forming part of that exhaled from the lungs; whilst another part will be applied to the oxidation of the Sulphur and Phosphorus, which are taken-in as such in the food, and which, after forming part of the solid tissues, are excreted in the condition of sulphuric and phosphoric acids, chiefly through the kidneys. It also appears, from the recent experiments of Dr. Bence Jones,† that the action of oxygen is exerted in the system upon Ammonia, and probably upon other products of decomposition of the nitrogenous tissues, in such a manner as to produce Nitrous or Nitric acid, which makes its appearance in the urine.

564. The absolute quantity of Carbonic Acid exhaled from the Lungs is liable to variation from so many sources, that no fixed standard can be assigned for it. The mean of a great number of observations, however, made in different modes, and under different circumstances, would give about 160 grains of Carbon per hour as the amount set free by a well-

* "Annales de Chimie et de Physique," 1849.

† "Philosophical Transactions," 1851; and "Medical Times," Aug. 30, 1851.

grown adult man, under ordinary circumstances. Taking this as the average of the twenty-four hours, the total quantity of Carbon thus daily expired from the Lungs would be 3840 grains, or 8 oz. Troy. The chief causes of variation are,—the Temperature of the surrounding Medium, Age, Sex, Development of the body, state of Health or Disease, Muscular Exertion or Repose, Sleep or Watchfulness, Period of the Day, and state of the Digestive process. These will now be considered in detail.

*a. Temperature of surrounding Medium.*—The amount of Carbonic Acid exhaled by warm-blooded animals is greatly *increased* by external *Cold*, and *diminished* by *Heat;* as is shown by the following results of comparative experiments upon the quantity set free by the same animals, at low, medium, and high temperatures, in periods of an hour (Letellier*):—

| | Temp. about 32°. *Grammes.* | Temp. 59°—68°. *Grammes.* | Temp. 86°—106°. *Grammes.* |
|---|---|---|---|
| A Canary . . . . | 0·325 | 0·250 | 0·129 |
| A Turtle-Dove . . | 0·974 | 0·684 | 0·336 |
| Two Mice . . . | 0·531 | 0·498 | 0·268 |
| A Guinea-Pig . . | 3·006 | 2·080 | 1·453 |

From this table it appears that the quantity of carbonic acid exhaled by Mammals between 86° and 106° is less than *half* that set free near the freezing-point; whilst that which is exhaled between 59° and 68° is but little more than *two-thirds* of the same amount. The diminution occasioned by heat is still more remarkable in Birds; which exhale at the highest temperature scarcely more than *one-third* of that set free at the lowest.—The observations of Vierordt† upon himself show that the same is true of the Human subject; a difference of 10° Fahr., according to him, producing a variation of rather more than two cubic inches in the amount of Carbonic Acid hourly expired.

*b. Age.*—The amount of Carbonic Acid exhaled increases in both sexes up to about the thirtieth year; it remains stationary until about the forty-fifth; and then diminishes. The following are the comparative results of experiments upon males of different ages, and of a moderate degree of muscular development (Andral and Gavarret‡):—

| *Age.* | *Carbon exhaled per hour.* | *Age.* | *Carbon exhaled per hour.* |
|---|---|---|---|
| 8 years . . | 77·0 grains. | 37 years . . | 164·7 grains. |
| 12 ,, . | 113·9 ,, | 48 ,, . | 161·7 ,, |
| 14 ,, . . | 126·2 ,, | 59 ,, . . | 154·0 ,, |
| 20 ,, . | 166·3 ,, | 68 ,, . | 147·8 ,, |
| 26 ,, . . | 169·4 ,, | 76 ,, . . | 92·4 ,, |

*c. Sex.*—At all ages beyond eight years, the exhalation is greater in Males than in Females. Nearly the same proportionate increase takes place, however, in Females, up to the time of puberty; when the quantity abruptly ceases to increase, and remains stationary so long as they continue to menstruate. When, however, menstruation has ceased, the exhalation of carbonic acid begins again to augment; and then again diminishes, with the advance of years, as in men. Should menstruation temporarily cease at any time, the exhalation of carbonic acid immediately

* "Annales de Chimie et de Physique," 1845.
† "Physiologie des Athmens," pp. 73—82.
‡ "Annales de Chimie et de Physique," 1843.

undergoes an increase, precisely as at the final cessation of the function. And during pregnancy, the exhalation increases in like manner. The following table of the comparative respiration of Females at different ages will serve at the same time for comparison with the preceding, so as to exhibit the general difference between the two sexes, at ages nearly corresponding; and also to indicate the peculiar modifications induced by the operations of the genital system (Andral and Gavarret) :—

| *Age.* | *Carbon exhaled per hour.* | *Age.* | *Carbon exhaled per hour.* |
|---|---|---|---|
| 10 years | 92·4 grains. | | |
| 13 „ | 97·0 „ | | |
| During Menstrual life. | | During Pregnancy. | |
| 15½ years | 97·0 grains. | 22 years | 129·3 grains. |
| 26 „ | 97·0 „ | 32 „ | 126·7 „ |
| 32 „ | 95·4 „ | 42 „ | 120·3 „ |
| 45 „ | 95·4 „ | | |
| After Cessation of Catamenia. | | | |
| 38 years | 120·3 grains. | 66 years | 104·7 grains. |
| 49 „ | 113·9 „ | 76 „ | 101·4 „ |
| 52 „ | 115·5 „ | 82 „ | 92·4 „ |
| 56 „ | 119·3 „ | | |

*d. Development of the Body.*—The more robust the individual, *cæteris paribus*, the more carbonic acid is exhaled; and the variation is much more influenced by the development of the muscular system, than by the height or weight, capacity of the chest, &c. Thus, a very strong man of twenty-six years of age exhaled at the rate of 217·1 grains per hour; when a man of moderate muscular power set free but 169·4 grains in the same time. Another robust man of sixty years of age exhaled at the rate of 209·4 per hour; another of similar constitution, and sixty-three years of age, at the rate of 190·9 grains per hour; and an old man of ninety-two years, who still preserved an uncommon degree of energy, and who in his younger days had boasted of extraordinary muscular powers, exhaled at the rate of 135·5 grains per hour. So, also, a remarkably vigorous young woman of nineteen years exhaled at the rate of 107·8 grains per hour; another of twenty-two years, rather less powerful, at the rate of 103·1 grains; and a strong woman of forty-four years (who had ceased to menstruate) 152·4 grains.—On the other hand, a slender man of forty-five years, in the enjoyment of good health, only exhaled at the rate of 132·4 grains per hour (Andral and Gavarret).

*e. State of Health or Disease.*—Upon this very important cause of variation, few accurate researches have yet been made. The *per-centage* of carbonic acid in the expired air has been found to be unusually great in the Exanthemata, and in chronic Skin-diseases (Macgregor*); and it has been stated to be diminished in Typhus (Malcolm†).—Thus, the average proportion in health being about 4·3 per cent (Vierordt); it has been seen at 8 per cent in confluent Small-pox, at 5 per cent in Measles, and at 7·2 per cent in a severe case of Ichthyosis which terminated fatally; whilst in Typhus the per-centage has been found to range from 1·18 to 2·50. But these statements do not indicate the total quantity exhaled in each

* "Edinb. Monthly Journal," 1843. † "Report of Brit. Assoc.," 1843, p. 87.

case.—The remarkable increase of the exhalation in cases of Chlorosis, has been already noticed; in four cases recorded by Hannover, the hourly expiration was 123·6, 118·6, 116·9, and 106·3 grains; the absolute quantity diminishing as the respirations increased in rapidity.—In chronic diseases of the respiratory organs, as might be anticipated, the amount of Carbonic acid exhaled undergoes a sensible diminution (Nysten* and Hannover†).—Further researches are much needed on this subject; but, for obvious reasons, they cannot be readily made in severe forms of disease.

*f. Muscular Exertion or Repose.*—The effect of bodily exercise, in moderation, is to produce a considerable increase in the amount of carbonic acid exhaled, both during its continuance, and for some little time subsequently to its cessation. According to the observations of Vierordt, the increase amounts to one-third of the quantity exhaled during rest; and it lasts for more than an hour afterwards, being manifested in the greater quantity of air respired, and in the larger per-centage of carbonic acid contained in it. If the exercise be prolonged, however, so as to occasion fatigue, it is succeeded by a diminished exhalation.—The connection between muscular exertion and the exhalation of carbonic acid, is most remarkably shown in Insects; in which animals we may witness the rapid transition between the opposite conditions of extreme muscular exertion, and tranquil repose; and in which the effects of these upon the respiratory process are not marked by that exhalation of carbonic acid, which is required in warm-blooded animals simply for the maintenance of a fixed temperature. Thus a Humble-Bee was found by Mr. Newport‡ to produce one-third of a cubic inch of carbonic acid, in the course of a single hour, during which its whole body was in a state of constant movement, from the excitement resulting from its capture; and yet, during the whole twenty-four hours of the succeeding day, which it passed in a state of comparative rest, the quantity of carbonic acid generated by it was absolutely less.

*g. Sleep or Watchfulness.*—The amount of carbonic acid exhaled during sleep is considerably less than that set free in the waking state. This is particularly shown by the experiments of Scharling;§ who confined the subjects of them in an air-tight chamber, within which they could sleep, take their meals, &c. Thus in one case, the hourly exhalation sank from [illegible]0 to 100, in another from 194·7 to 122·3, and in another from 99 to [illegible]·1. The cause of this result is partly to be sought in the cessation of all muscular exertion (save that concerned in the maintenance of the respiration); and partly in the diminution in the dissipation of the heat of the body itself.

*h. State of the Digestive Process.*—It is well established, that the exhalation of carbonic acid is greatly increased by eating, and that it is diminished by fasting. Thus Prof. Scharling states the hourly exhalation to have increased in one instance from 145 to 190, after breakfast and a walk; in another from 140 to 177, after breakfast alone; and in another from 111·9 to 188·9, after dinner. The observations of Vierordt are to

* "Recherches de Physiologie et de Chimie Pathologique," 1811.

† "De Quantitate relativa et absoluta Acidi Carbonici ab Homine Sano et Ægroto exhalati," 1845.

‡ "Philos. Transact.," 1836.

§ "Ann. der Chem. und Pharm.," 1843; transl. in 'Ann. de Chim. et de Phys.,' 1843.

the same effect.—It is remarkable that Alcoholic drinks have a tendency to *diminish* the exhalation of carbonic acid, especially when taken into an empty stomach; and it appears from the experiments of Dr. Prout,* which have been confirmed as to many points by those of Vierordt, that this diminution continues so long as the alcohol remains unconsumed in the system, and is then followed by a marked increase in the per-centage of carbonic acid in the inspired air; thus showing that the presence of alcohol tends to prevent the normal oxidation and elimination of the excrementitious matters which the blood may contain. Strong tea is said to have the same effect (Prout, Vierordt).—The quantity is also decreased by depressing affections of the mind (Prout, Vierordt, and Scharling).

*i. Period of the Day.*—Independently of these variations, which have their source in the condition of the individual, there is reason to believe that there is a diurnal cycle of change in the quantity of carbonic acid exhaled, the *maximum* being (cæteris paribus) before and after noon, and the *minimum* before and after midnight. From the experiments of Scharling upon the Human subject, it would appear that the average proportion exhaled by day to that exhaled by night, is as $1\frac{1}{4}$ to 1; and this difference does not seem to be affected by sleep or wakefulness. How far it is to be accounted for by other differences in the condition of the system, it does not seem easy to determine. But it is pretty obviously associated with a difference in the power of generating heat; for according to the observations of Chossat (CHAP. XIII.), there is a like diurnal variation in the temperature of Birds; and most persons are conscious of a greater difficulty in bearing exposure to cold between midnight and early morning, than at any other period in the twenty-four hours.

565. The aeration of the blood may take place, not only by means of the Lungs, but also in some degree through the medium of the Cutaneous surface. In some of the lower tribes of animals, indeed, this is a very important part of their respiratory process: and even in certain Vertebrata, the cutaneous respiration is capable of supporting life for a considerable time. This is especially the case in the Batrachia, whose skin is soft, thin, and moist; and the effect is here the greater, since, from the small proportion of the blood that has passed through the lungs, that which circulates through the system is very imperfectly arterialized. By the experiments of Bischoff it was ascertained that, even after the lungs of a Frog had been removed, a quarter of a cubic inch of carbonic acid was exhaled from the skin, during eight hours. Experiments which have been made on the Human subject leave no room for doubt, that a similar process is effected through the medium of his general surface, although in a very inferior degree; for by confining the body in a close chamber, into which the products of cutaneous respiration could freely pass, whilst the pulmonary respiration was measured by a distinct apparatus, Prof. Scharling† ascertained that the proportion of carbonic acid given off by the Skin is from 1-30th to 1-60th of that exhaled from the Lungs during the same period of time. Moreover, it has been observed, not unfrequently, that the livid tint of the skin which supervenes in Asphyxia, owing to the non-arterialization of the blood in the lungs, has given place after death

* "Thomson's Annals of Philosophy," vols. ii. and iv.

† "Ann. der Chem. und Pharm.," 1846.

the fresh hue of health, owing to the reddening of the blood in the taneous capillaries by the action of the atmosphere upon them; and it :s not seem improbable that, in cases of obstruction to the due action the lungs, the exhalation of carbonic acid through the skin may dergo a considerable increase; for we find a similar disposition to arious action in other parts of the excreting apparatus. Moreover, ere is evidence that the interchange of gases between the air and the od, through the skin, has an important share in keeping up the tem-rature of the body (CHAP. XIII.); and we find the temperature of the face much elevated in many cases of pneumonia, phthisis, &c., in which lungs seem to perform their function very insufficiently.

566. The total amount of Carbonic acid daily given off from the Skin l Lungs may be estimated in another mode; namely, by determining total amount of Carbon contained in the *ingesta*, and the amount reted in other ways, making allowance for the difference in weight (if y) of the body. In this mode, Prof. Liebig came to the conclusion that average amount of carbon exhaled by soldiers in barracks, was 13·9 oz. essian) or very nearly 14 oz. troy.* From similar collective observa-ns upon the inmates of the Bridewell at Marienschloss (a prison where our is enforced) he calculates that each individual exhaled 10·5 oz. of bon daily in the form of carbonic acid; while in a prison at Giessen, ose inmates are deprived of all exercise, the daily average was but oz.† It has been shown by Prof. Scharling,‡ that the total amount carbon contained in the daily allowance of food and drink in the nish Navy, is somewhat less than 10·5 oz.; and as we shall presently that from 1-10th to 1-12th of the carbon ingested passes off through ner channels, scarcely more than 9·5 oz. of this amount can be con-ned by the respiratory process.—A very exact estimate, though based more limited data, has been recently made by M. Barral;§ who perimented upon himself (æt. 29) in winter (A) and in summer (B), on a boy of 6 years old (C), upon a man of 59 years old (D), and upon unmarried woman of 32 years (E). The following table gives the results ich he obtained, from an average of five days, in regard to the disposal the Carbon of the food; those which relate to its Hydrogen and ygen will be noticed hereafter (§ 569).

| | *Weight of Body.* | *Carbon of Food.* | *Carbon excreted.* | | |
|---|---|---|---|---|---|
| | | | In Fæces. | In Urine. | By Exhalation. |
| A | 104·5 lbs. | 5654·1 grs. | 236·2 grs. | 234·6 grs. | 5183·3 grs. |
| B | —— | 4090·0 „ | 137·4 „ | 211·5 „ | 3741·1 „ |
| C | 33 „ | 2382·3 „ | 149·7 „ | 67·9 „ | 2164·7 „ |
| D | 129·1 „ | 5123·0 „ | 210·0 „ | 327·3 „ | 4585·7 „ |
| E | 134·6 „ | 4520·8 „ | 64·8 „ | 216·1 „ | 4239·9 „ |

* "Animal Chemistry," 3rd edit. p. 13. The mode in which this estimate was made, vever, was very far from exact; as it rests on the assumption that the carbon of the fæces urine was no more than equal to that of certain *extra* articles of diet supposed to have n consumed, and that *all* the carbon of the regular allowance of bread, meat, and etables, must have passed-off by the atmosphere. Its great discordance with other results ves little room for doubt, that even if not far from being true for the particular case, it not be admitted as representing the usual average.

† Op. cit. p. 46.

‡ "Ann. der Chem. und Pharm.," 1846. § "Ann. de Chim. et de Phys.," tom. xxv.

Thus the average amount of carbon daily consumed in pulmonary and cutaneous exhalation by M. Barral himself, was in winter 5183·3 grains, or 10·8 oz. troy; whilst in summer it was but 3741·1 grains, or 7·8 oz. troy; this difference is quite conformable to what might have been anticipated from the results of a different mode of experimenting (§ 564 *a*); and it throws some light on the discrepancies in the results of other measurements, to find that the seasonal variation is scarcely less than one-third of the mean between these two amounts. The other results correspond closely with the statements of MM. Andral and Gavarret, in regard to the higher proportion of carbonic acid exhaled (as compared with the bulk of the body) by children; and the smaller proportion thrown off by men advanced in years, and by women.

567. It is not only by an oxygenated atmosphere, that the removal of Carbonic acid from the blood may be effected. For although it was formerly supposed that the exhaled carbonic acid is generated in the lungs by the combination of atmospheric oxygen with the carbonaceous matters of the blood, and that the inhalation of oxygen is therefore immediately necessary for its production, yet it is now quite certain that this carbonic acid exists preformed in venous blood, and that the oxygen introduced is carried into the arterial circulation, instead of being at once returned to the air in the state of carbonic acid. That this (which was first advanced by Lagrange and Hassenfratz) is the true view of the case, is proved by experiments of two kinds;—those, namely, which have shown that a larger proportion of oxygen exists in arterial blood, and a larger proportion of carbonic acid in venous blood (§ 163);—and those which demonstrate that an exhalation of carbonic acid may continue for a considerable period (in cold-blooded animals especially), during which the animal is breathing an atmosphere in which no oxygen exists. Thus it was shown by Spallanzani,* that Snails might be kept for a long time in Hydrogen, without apparent injury to them; and that during this period they disengaged a considerable amount of Carbonic acid. Dr. Edwards† subsequently ascertained that, when Frogs were kept in hydrogen for several hours, the quantity of carbonic acid exhaled was fully as great as it would have been in atmospheric air, or even greater; this latter fact, if correct, may be accounted-for by the superior displacing power which (on the laws of the diffusion of gases) hydrogen possesses for carbonic acid. Collard de Martigny‡ repeated this experiment in Nitrogen, with the same results. In both sets of experiments, the precaution was used of compressing the flanks of the animal, previously to immersing it in the gas, so as to expel from the lungs whatever mixture of oxygen they might contain. These experiments have been since repeated by Müller and Bergemann, who took the additional precaution of removing, by means of the air-pump, all the atmospheric air that the lungs of the frog might previously contain, together with the carbonic acid that might exist in the alimentary canal. They found in one of their experiments, that the quantity of carbonic acid exhaled in hydrogen was nearly a cubic inch in 6½ hours; and in another, that nearly the same amount was given off in nitrogen, though this required rather a longer period. It appears from the

* "Mémoires sur la Respiration," traduits par Senebier, Genève, 1804.

† "De l'Influence des Agens Physiques sur la Vie;" Paris, 1824.

‡ 'Recherches Expérimentales,' &c. in Magendie's "Journal de Physiologie," tom. x.

ble of their results,* that the amount was not ordinarily greater in the :periments which were prolonged for twelve or fourteen hours, than in .ose which were terminated in half the time; hence it may be inferred, at the quantity which the blood is itself capable of disengaging is nited, and that the absorption of oxygen is necessary to enable carbonic .id to be set free from the body.—It is impossible, however, for an adult ird or Mammal to sustain life for any considerable time in an atmo- phere deprived of oxygen; since the greatly-increased rapidity and energy ' all their vital operations, necessitate a much more constant supply of iis vivifying agent than is needed by the inferior tribes; and, as we shall resently see, the capillary action requisite for the passage of the blood irough the lungs will not take place without it. But Dr. Edwards has iown, that young Mammalia can sustain life in an atmosphere of hydro- en or nitrogen, for a sufficient length of time to exhale a sensible amount ' carbonic acid; so that the character of the process is clearly proved to e the same in them, as in Reptiles and Invertebrata.

568. Much discussion has taken place with regard to the degree in hich the proportion of *Nitrogen* in the air is affected by Respiration. It ems probable that the absorption and exhalation of this gas are con- nually taking place; but that the two amounts usually nearly balance ich other.† On the whole, however, there is adequate reason to believe iat Nitrogen is usually given off; this being the joint result of the ialysis of the expired air, and of the comparison of the nitrogen given ff in the other excretions with that ingested as a constituent of the od. Of the experiments made in the former of these methods, the iost accurate are those of MM. Regnault and Reiset, whose general con- .usions are as follows:—(1). That warm-blooded animals subjected to ieir ordinary regimen exhale nitrogen, but never in larger proportion ian 1-50th, and sometimes in less than 1-100th, of the oxygen con- imed:—(2). That in a state of inanition, animals usually absorb nitro- en:—(3). That animals whose usual diet has been changed, usually bsorb oxygen until they are accustomed to their new food.‡—Of the xperiments made according to the second method, those of M. Boussin- ault upon turtle-doves, and those of M. Barral upon the human subject, ppear to be trustworthy. The former states that the surplus of nitro- en in the food of the bird, above that excreted by the kidneys and intes- inal canal, is $2\frac{1}{2}$ grains daily;§ whilst the latter gives the following as he results of his observations upon himself and the other individuals lready referred-to (§ 566):—

| | *Nitrogen in Food.* | *Nitrogen excreted.* | | |
|---|---|---|---|---|
| | | Urine. | Fæces. | Lungs and Skin. |
| A | 432·3 grs. | 168·3 grs. | 43·2 grs. | 220·8 grs. |
| B | 327·3 „ | 151·3 „ | 20·1 „ | 155·9 „ |
| C | 121·9 „ | 47·8 „ | 27·8 „ | 46·3 „ |
| D | 421·5 „ | 234·6 „ | 38·6 „ | 148·3 „ |
| E | 345·8 „ | 154·4 „ | 12·3 „ | 179·1 „ |

* Müller's "Elements of Physiology," translated by Baly, p. 338.

† For the considerations which render this probable, see especially Dr. W. F. Edwards On the Influence of Physical Agents on Life," Part iv. chap. xvi. sect. 2, 3.

‡ "Ann. de Chim. et de Phys.," 1849.

§ "Comptes Rendus," 1846.

In cases A, B, and E, the amount of Nitrogen which (being otherwise unaccounted-for) must be considered to have passed off by the lungs and skin, was about 1-75th of the oxygen consumed; a proportion which accords very well with that deduced by MM. Regnault and Reiset from their experiments on animals. In case D, however, it was only 1-97th; and in case C (that of a child of six years old), it was as little as 1-143rd. —It will be remembered that Nitrogen exists in an uncombined state in the blood (§ 163); its per-centage, however, is continually varying; and no constant difference is observable between the proportions yielded by arterial and venous blood respectively.

[The alterations effected in the *Blood* by Respiration have already been fully considered. See §§ 163-166.]

569. *Exhalation and Absorption through the Lungs.*—The Air expired from the lungs differs from that which was introduced into them, not merely in the altered proportions of its Oxygen, Nitrogen, and Carbonic acid, but also in having received (under ordinary circumstances at least) a large addition to its watery vapour. This it doubtless acquires, in accordance with physical laws, through its exposure to the warm blood which is spread out over a very extensive surface, the intermediate membrane being extremely permeable; and the variations in its amount will depend upon the physical conditions under which that exposure takes place. The air expired in ordinary respiration is charged with as much watery vapour as saturates it at the temperature of the body; and consequently the amount of watery vapour thus exhaled, will vary (for equal volumes of air at any given temperature) in the inverse proportion to that which the air previously contained. But when the air is very cold and very dry, and the respiration is unusually rapid, it may not remain sufficiently long in the air-cells to be raised to the temperature of the body, or to be fully saturated with moisture. The amount of watery vapour exhaled, moreover, will of course depend in part upon the quantity of air which passes through the lungs. And from these causes of variation, it happens that the amount of watery vapour exhaled in twenty-four hours ranges from about 6 to 27 oz.; its usual range, however, being between 16 and 20 oz.—Of the fluid ordinarily exhaled with the breath, a part doubtless proceeds from the moist lining of the nostrils, fauces, &c.; but it is indisputable that the greater proportion of it comes from the lungs, since, when the respiration is entirely performed through a canula introduced into the trachea, the amount of watery vapour which the breath contains is still very considerable. Of the proper pulmonary exhalation, there can be no doubt that the greater part is the mere surplus-water of the blood, and especially of the crude fluid which has been newly introduced into the circulating current by the process of nutritive absorption. But there is strong evidence that Hydrogen as well as carbon undergoes combustion in the system; and that a portion of the exhaled aqueous vapour is the product of that combustion. For of the hydrogen which the food contains, not more than from 1-8th to 1-10th passes off by the other excretions, the remaining 7-8ths or 9-10ths being exhaled in the condition of watery vapour from the lungs. A portion of the oxygen which this vapour contains, is supplied by the food; but there is a considerable surplus of hydrogen; and this can only be converted into water, at the expense of oxygen derived from the atmosphere. Upon

this point the experiments of M. Barral (loc. cit.) gave the following results.

| | *Oxygen exhaled.* | *Equiv. of Hydrogen.* | *Hydrogen exhaled.* | *Difference.* |
|---|---|---|---|---|
| A | 3841·4 grs. | 480·2 grs. | 801·3 grs. | 321·1 grs. |
| B | 2757·6 „ | 344·7 „ | 597·5 „ | 252·8 „ |
| C | 1880·6 „ | 235·1 „ | 330·4 „ | 95·3 „ |
| D | 3795·1 „ | 474·4 „ | 662·3 „ | 187·9 „ |
| E | 3140·5 „ | 392·5 „ | 643·8 „ | 251·3 „ |

Thus it appears that, of the Hydrogen exhaled from the lungs and skin of M. Barral, in the condition of watery vapour, not less than 321·1 grs. in winter, and 252·8 grains in summer, must have been converted into water by oxygen derived from the air; and this calculation would give 2889·9 grs. (6 oz. troy) for the winter, and 2275·2 grs. (4·7 oz. troy) for the summer, as the amount of water thus generated in the combustive process. This, however, can only be regarded as an approximation to the truth; since there are many circumstances not taken into account in the computation, by which the estimate may be affected.

570. The fluid thrown off from the lungs is not pure Water. It holds in solution, as might have been expected, a considerable amount of carbonic acid, and also some animal matter; the exact nature of the latter, which according to Collard de Martigny (op. cit.) constitutes about 3 parts in 1000, has not been ascertained; but from the recent inquiries of Mr. R. A. Smith,* it would appear to be an albuminous substance in a state of decomposition. If the fluid be kept in a closed vessel, and be exposed to an elevated temperature, a very evident putrid odour is exhaled by it. Every one knows that the breath itself has, occasionally in some persons, and constantly in others, a fœtid taint; when this does not proceed from carious teeth, ulcerations in the air-passages, disease in the lungs, or other similar causes, it must result from the excretion of the odorous matter, in combination with watery vapour, from the pulmonary surface. That this is the true account of it seems evident, from the analogous phenomenon of the excretion of turpentine, camphor, alcohol, and other odorous substances, which have been introduced into the venous system, either by natural absorption, or by direct injection; and also from the suddenness with which it often manifests itself, when the digestive apparatus is slightly disordered, apparently in consequence of the entrance of some mal-assimilated matter into the blood. Among the substances occasionally thrown off by the lungs, phosphorus deserves a special mention, on account of the peculiarity of the form under which it is eliminated; for it has been found that if phosphorus be mixed with oil, and be injected into the blood-vessels, it partly escapes in an unoxidized state from the lungs, rendering the breath luminous.† And this luminous breath has also been observed in spirit-drinkers; in whom the oxidation of the effete matters of the system is impeded, in consequence of the demand set up by the alcohol ingested for the oxygen introduced (§ 564, *h*).

571. Not only exhalation, but also (under peculiar circumstances) *absorption* of fluid may take place through the Lungs. Thus Dr.

* "Philosophical Magazine," vol. xxx. p. 478.

† "Casper's Wochenschrift," 1849, band 15.

Madden* has shown that, if the vapour of hot water be inhaled for some time together, the total loss by exhalation is so much less than usual, as to indicate that the cutaneous transpiration is partly counterbalanced by pulmonary absorption; the pulmonary exhalation being at the same time entirely checked. It is probable that, if the quantity of fluid in the blood had been previously diminished by excessive sweating, or by other copious fluid secretions, the pulmonary absorption would have been much greater. Still in the cases formerly mentioned (§ 469), in which a large increase in weight could only be accounted-for on the supposition of absorption of water from the atmosphere, it seems probable that the cutaneous surface was chiefly concerned; for it can only be when the air introduced into the lungs is *saturated* with watery vapour, that the usual exhalation will be checked, or that any absorption can take place.

572. That absorption of other volatile matters diffused through the air, is, however, continually taking place by the lungs, is easily demonstrated. A familiar example is the effect of the inhalation of the vapour of Turpentine upon the urinary excretion. It can only be in this manner that those gases act upon the system, which have a noxious or poisonous effect, when mingled in small quantities in the atmosphere; and it is most astonishing to witness the extraordinary increase in potency which many substances exhibit, when they are brought into relation with the blood in the gaseous form. The most remarkable example of this kind is afforded by Arseniuretted Hydrogen, the inspiration of a few hundredths of a grain of which has been productive of fatal consequences, the resulting symptoms being those of arsenical poisoning. Next to this, perhaps, in deleterious activity, is Sulphuretted Hydrogen; but it would seem that the effects of this upon the Human subject are scarcely so violent as they are upon animals; for though it has been found that the presence of 1-1500th part of it in the respired air will destroy a bird in a very short time, that 1-800th part suffices to kill a dog, and that 1-250th part is fatal to a horse, yet M. Parent-Duchâtelet has affirmed that workmen habitually breathe with impunity an atmosphere containing *one per cent*, and that he himself has respired, without serious symptoms ensuing, air which contained *three per cent.* There can be no doubt, however, that the *continued* inhalation of air thus contaminated, would be speedily fatal. Sulphuretted hydrogen and Hydro-sulphuret of ammonia are given off from most forms of decaying animal and vegetable matter; and it is undoubtedly to the accumulation of these gases, that the fatal results which sometimes ensue from entering sewers are to be chiefly attributed.—Carburetted hydrogen is another gas whose effects are similar; but a larger proportion of it is required to destroy life.—Carbonic acid gas, also, appears to be absorbed by the lungs, when a large proportion of it is contained in the atmosphere. The accumulation of this gas in the blood, when the respired air is charged with it even to a moderate amount, might be attributed to the impediment thus offered to its ordinary exhalation (§ 56): but the following experiment appears to prove that it may be actually absorbed into the blood, and that it will thus exert a real poisonous influence, and not merely produce an asphyxiating effect. It was found by Rolando, that the air-tube of one lung of the land-tortoise

* "Prize Essay on Cutaneous Absorption," p. 55.

may be tied, without apparently doing any material injury to the animal, as the respiration performed by the other is sufficient to maintain life for some time; but, having contrived to make a tortoise inhale carbonic acid by one lung, whilst it breathed air by the other, he found that the animal died in a few hours.*—Cyanogen is another gas which has an actively-poisonous influence upon animals, when absorbed into the lungs; its agency, also, is of a narcotic character.

573. It is singular that the effects of the respiration of pure Oxygen should not be dissimilar. At first, the rapidity of the pulse and the number of the respirations are increased, and the animal appears to suffer little or no inconvenience for an hour; but symptoms of coma then gradually develop themselves, and death ensues in six, ten, or twelve hours. If the animals are removed into the air before the insensibility is complete, they then quickly recover. When the body is examined, the heart is seen beating strongly, while the diaphragm is motionless; the whole blood in the veins, as well as in the arteries, is of a bright scarlet colour; and several of the membranous surfaces have the same tint. The blood is observed to coagulate with remarkable rapidity; and it is to the alteration in its properties, occasioned by hyper-arterialization, and indicated by this condition, that we are probably to attribute the fatal result. There can be no doubt that in this instance, an undue amount of oxygen is absorbed; and it does not seem unlikely that one cause of the fatal result, is a stagnation of the blood in the systemic capillaries, consequent upon the want of sufficient change in its passage through them. —When Nitrogen or Hydrogen is breathed for any length of time, death results from the deprivation of Oxygen, rather than from any deleterious influence which these gases themselves exert.—Death is also caused by the inhalation of several gases of an irritant character, such as Sulphurous, Nitrous, and Muriatic acids; but it is doubtful how far they are absorbed, or how far their injurious effects are due to the abnormal action which they excite in the lining membrane of the air-cells and tubes.—It cannot be doubted, that Miasmata and other morbific agents diffused through the atmosphere, are more readily introduced into the system through the pulmonary surface than by any other; and our aim should therefore be directed to the discovery of some counteracting agents, which can be introduced in the same manner. The Pulmonary surface affords a most advantageous channel for the introduction of certain medicines that can be raised in vapour, when it is desired to affect the system with them speedily and powerfully; such is pre-eminently the case with those Anæsthetic agents, ether and chloroform, whose introduction into the various departments of Medical and Surgical practice constitutes a most important era in the history of the healing art; also with Mercury,† Iodine, Tobacco, Stramonium, &c.

* The fatal result of breathing the fumes of charcoal is, therefore, not simple Asphyxia, such as would result from breathing hydrogen or nitrogen.—Other volatile products are set free in the combustion of charcoal, besides carbonic acid. Mr. Coathupe (loc. cit.) states these to be Carbonate, Muriate, and Sulphate of Ammonia, Carbonic Oxide, Oxygen, Nitrogen, Watery vapour, and Empyreumatic Oil: to these, Sulphurous acid may appear to be properly added.

† The beneficial results of the introduction of Mercury by inhalation are strikingly set forth in Mr. Langston Parker's Essay on "The Treatment of Secondary, Constitutional, and Confirmed Syphilis."

### 3.—*Effects of Suspension or Deficiency of Respiration.*

574. We have now to consider the results of the cessation of the Respiratory function, and the consequent retention of Carbonic Acid in the blood. If this be sufficiently prolonged, a condition ensues, to which the name of *Asphyxia* has been given; the essential character of which is the cessation of muscular movement, and shortly afterwards of the circulation; with an accumulation of blood in the venous system. The time which is necessary for life to be destroyed by Asphyxia varies much, not only in different animals, but in different states of the same. Thus, warm-blooded animals are much sooner asphyxiated than Reptiles or Invertebrata; on the other hand, a hybernating Mammal supports life for many months, with a respiration sufficiently low to produce speedy asphyxia if it were in a state of activity. And among Mammalia and Birds, there are many species which are adapted, by peculiarities of conformation, to sustain a deprivation of air for much more than the average period.* Excluding these, it may be stated as a general fact, that, if a warm-blooded animal in a state of activity be deprived of respiratory power, its muscular movements (with the exception of the contraction of the heart) will cease within five minutes, often within three; and that the circulation generally fails within ten minutes.—Many persons, however, are capable of sustaining a deprivation of air for two, three, or even four minutes,† without insensibility or any other injury; but this power, which seems possessed to the greatest degree by the divers of Ceylon, can only be acquired by habit. The period during which remedial means may be successful in restoring the activity of the vital and animal functions, is not, however, restricted to this. There is one well-authenticated case, in which recovery took place after a continuous submersion of fifteen minutes;‡ and many others are on record, of the revival of

* Thus, the Cetacea contain far more blood in their vessels, than do any other Mammalia; and these vessels are so arranged, that both arteries and veins are in connection with large reservoirs or diverticula. The reservoirs belonging to the former are usually full; but when the Whale remains long under water, the blood which they contain is gradually introduced into the circulation, and, after becoming venous, accumulates in the reservoirs connected with the venous system. By means of this provision, the Whale can remain under water for more than an hour.

† Dr. Hutchinson states that any man of ordinary 'vital capacity' can pass two minutes without breathing, if he first makes five or six forcible inspirations and expirations, so as to cleanse the lungs of the old air, and then fills his chest as completely as he can. "For the first 15 seconds a giddiness will be experienced; but when this leaves us, we do not feel the slightest inconvenience for want of air." (See "Cyclop. of Anat. and Phys.," vol. iv. p. 1066.)

‡ The following are the facts of this case, as narrated by Marc ("Manuel d'Autopsie Cadavérique Médico-Légale," p. 165) on the authority of Prater.—A woman convicted of infanticide was condemned to die by drowning. This punishment was formerly inflicted in Germany according to the now obsolete Caroline law, the culprit being inclosed in a sack with a cock and a cat, and sunk to the bottom of the water. In this instance, the woman, after having been submerged for a quarter of an hour, was drawn up, and *spontaneously* recovered her senses. She stated that she had become insensible at the moment of her submersion; a circumstance which adds considerable weight to the supposition, based upon the post-mortem appearances in many cases of drowning, that death often takes place as much by Syncope (or primary failure of the heart's action, consequent upon sudden and violent emotion, or upon physical shock) as by Asphyxia. If the reality of this state of Syncopal Asphyxia be admitted, there does not seem any adequate reason for limiting the

drowned persons after an interval of half an hour, or even more; but there is not the same certainty in regard to these, that the individuals may not have occasionally risen to the surface and taken breath there. It is not improbable, however, that in some of these cases a state of Syncope had come on at the moment of immersion, through the influence of fear or other mental emotion, concussion of the brain, &c.; so that, when the circulation was thus enfeebled, the deprivation of air would not have the same injurious effect, as when this function was in full activity. The case would then closely resemble that of a hybernating animal; for in both instances the being might be said to live very slowly, and would therefore not require the usual amount of respiration. The condition of the still-born infant is in some respects the same; and re-animation has been successfully attempted, when nearly half an hour had intervened between birth and the employment of resuscitating means, and when probably a much longer time had elapsed from the period of the suspension of the circulation.

575. It has now been sufficiently proved, both by experiment and by pathological observation, that the first effect of the non-arterialization of the blood in the lungs, is the retardation of the fluid in their capillaries; of which the accumulation in the venous system, and the deficient supply to the arterial, are the necessary consequences. It is some time, however, before a complete stagnation takes place from this cause; since, as long as the proportion of oxygen which remains in the air in the lungs is considerable, and that of the carbonic acid is small, so long will some imperfectly-arterialized blood find its way back to the heart, and be transmitted to the system. This blood exerts a depressing influence upon the nervous centres, which is aided by the diminution that gradually takes place in the quantity of blood propelled to them; and thus the powers of the Sensorial centres are suspended, so that the individual becomes unconscious of external impressions; whilst the activity of the Medulla Oblongata also becomes diminished, so that the respiratory movements are enfeebled. The progressive exhaustion of the oxygen of the air in the lungs, and the accumulation of carbonic acid in the blood, increase the obstruction in the pulmonary capillaries; less and less blood is delivered to the systemic arteries, and what is thus transmitted becomes more and more venous; the nervous centres are now completely paralyzed, and the respiratory movements cease; and the deficient supply of blood, with the depravation of its quality, act injuriously upon the muscular system also, and especially weaken the contractility of the heart (§ 324). In this enfeebled state, the final cessation of its movements seems attributable to two distinct causes, acting on the two sides respectively; for on the right side it is the result of the over-distension of the walls of the ventricle, owing to the accumulation of venous blood; and on the left to deficiency of the stimulus necessary to excite the movement, which is no longer sustained by its spontaneous motility (§ 499). The heart's contractility is not finally lost, nearly as soon as its movements cease; for the action of the right ventricle may be renewed, for some time after it has ceased, by withdrawing a portion of its contents,—either through the pulmonary

possible persistence of vitality in a submerged body, even to half an hour; especially if the temperature of the water be such as not to cause any rapid abstraction of its heat.

artery, their natural channel,—or, more directly, by an opening made in its own parietes, in the auricle, or in the jugular vein (§ 504). On the other hand, the left ventricle may be again set in action, by renewing its appropriate stimulus of arterial blood. Hence, if the stoppage of the circulation have not been of too long continuance, it may be renewed by artificial respiration; for the replacement of the carbonic acid by oxygen in the air-cells of the lungs, restores the circulation through the pulmonary capillaries; and thus at the same time relieves the distension of the right ventricle, and conveys to the left the due stimulus to its actions.—Of the mode in which the Pulmonary circulation is thus stagnated by the want of oxygen, and renewed by its ingress into the lungs, no other consistent explanation can be given, than that which is based on the doctrine already laid down in regard to the capillary circulation in general (§ 527); namely that the performance of the normal reaction between the blood and the surrounding medium (whether this be air, water, or solid organized tissue) is a condition necessary to the regular movement of the blood through the extreme vessels. That no mechanical impediment to its passage is created (as some have maintained) by the want of distension of the lungs, has been fully proved by the experiments of Dr. J. Reid on the induction of Asphyxia by the respiration of azote. And that a contraction of the small arteries and capillaries, under the stimulus of venous blood, cannot be legitimately assigned as the cause of the obstruction, is evident from the consideration brought to bear upon it by the same excellent experimenter (§ 526); namely, the *suddenness* with which the flow is renewed on the admission of oxygen, as contrasted with the *slowness* with which arteries dilate after the removal of the cause of their contraction.*

576. It cannot be necessary here to dwell upon the fact, that by the repeated passage of the same air through the lungs, it may, though originally pure and wholesome, be so strongly impregnated with carbonic acid, and may lose so much of its oxygen, as to become utterly unfit for the continued maintenance of the aerating process; so that the individual who continues to respire it, shortly becomes asphyxiated. There are several well-known cases, in which the speedy death of a number of persons confined together has resulted from neglect of the most ordinary precautions for supplying them with air. That of the "Black Hole of Calcutta" which occurred in 1756, has acquired an unenviable pre-eminence, owing to the very large proportion of the prisoners, 123 out of 146, who died during *one night's* confinement in a room 18 feet square, only provided with two small windows; and it is a remarkable confirmation of the views formerly stated (§ 210), and presently to be again adverted-to, that of the 23 who were found alive in the morning, many were subsequently cut-off by 'putrid fever.' Such catastrophes have occurred even in this country, from time to time, though usually upon a smaller scale; there has happened one at no distant date, however, which rivalled it in magnitude. On the night of the 1st of December, 1848,

* For a fuller discussion of the Pathology of Asphyxia, see the "Cyclop. of Anat. and Phys.," art. 'Asphyxia,' by Prof. Alison; the "Library of Practical Medicine," vol. iii. art. 'Asphyxia,' by the Author; the Experimental Essay by Dr. J. Reid, 'On the Order of Succession in which the Vital Actions are arrested in Asphyxia,' in the "Edinb. Med. and Surg. Journ.," 1841, and in his "Anat., Physiol., and Pathol. Researches;" and the Experimental Inquiry by Mr. Erichsen, in the "Edinb. Med. and Surg. Journ.," 1845.

the deck-passengers on board the Irish steamer Londonderry were ordered below by the Captain, on account of the stormy character of the weather; and although they were crowded into a cabin far too small for their accommodation, the hatches were closed down upon them. The consequence of this was, that out of 150 individuals, no fewer than 70 were suffocated before the morning.

577. It cannot be too strongly impressed upon the Medical practitioner, however, and through him upon the Public in general, that the continued respiration of an atmosphere charged in a far inferior degree with the exhalations from the Lungs and Skin, is among the most potent of all the 'predisposing causes' of disease, and especially of those *zymotic* diseases whose propagation seems to depend upon the presence of fermentible matter in the blood. That such is really the fact, will appear from evidence to be presently referred-to; and it is not difficult to find a complete and satisfactory explanation of it. For, as the presence of even a small per-centage of carbonic acid in the respired air, is sufficient to cause a serious diminution in the amount of carbonic acid thrown off and of oxygen absorbed (§ 561), it follows that those oxidating processes which minister to the elimination of effete matter from the system must be imperfectly performed, and that an accumulation of substances tending to putresence must take place in the blood. Hence there will probably be a considerable increase in the amount of such matters in the pulmonary and cutaneous exhalation; and the unrenewed air will become charged, not only with carbonic acid, but also with organic matter in a state of decomposition, and will thus favour the accumulation of both these morbific substances in the blood, instead of effecting that constant and complete removal of them, which it is one of the chief ends of the respiratory process to accomplish.—It has been customary to consider the consequences of imperfect respiration, as exerted merely in promoting an accumulation of carbonic acid in the system, and in thus depressing the vital powers, and rendering it prone to the attacks of disease. But the deficiency of oxygenation, and the consequent increase of putrescent matter in the body, must be admitted as at least a concurrent agency; and when it is borne in mind that the atmosphere in which a number of persons have been confined for some time, becomes actually offensive to the smell in consequence of the accumulation of such exhalations, and that this accumulation exerts precisely the same influence upon the spread of zymotic disease (as will presently appear) that is afforded by the diffusion of a sewer-atmosphere through the respired air, it scarcely admits of reasonable doubt that the pernicious effect of over-crowding is exerted yet more through its tendency to promote putrescence in the system, than through the obstruction it creates to the due elimination of carbonic acid from the blood. For it is to be remembered, that whilst the *complete* oxidation of the effete matters will carry them off by the lungs in the form of carbonic acid and water, leaving urea and other highly-azotized products to pass-off by the kidneys, an *imperfect* oxidation will only convert them into those peculiarly offensive products which characterize the fæcal excretion (§ 458).*

* It is a remarkable confirmation of Prof. Liebig's analogy between the imperfect oxidation of effete matters within the body, and that combustion in a lamp or furnace insufficiently

578. Of the remarkable tendency of the Respiration of an atmosphere charged with the emanations of the Human body, to favour the spread of Zymotic diseases, a few characteristic examples will now be given.—All those who have had the widest opportunities of studying the conditions which predispose to the invasion of Cholera, are agreed that *overcrowding* is among the most potent of these; and the "Report of the General Board of Health" on the late epidemic, contains numerous cases in which this was most evident, of which the two following may be selected.—In the autumn of 1849, a sudden and violent outbreak of Cholera occurred in the Workhouse of the town of Taunton; no case of cholera having previously existed, and none subsequently presenting itself, among the inhabitants of the town in general, though diarrhœa was prevalent to a considerable extent. The building was altogether badly constructed, and the ventilation deficient; but this was especially the case with the school-rooms, there being only about 68 cubic feet of air for each girl, and even less for the boys. On Nov. 3, one of the inmates was attacked with the disease; in ten minutes from the time of the seizure, the sufferer passed into a state of hopeless collapse; within the space of forty-eight hours from the first attack, 42 cases and 19 deaths took place; and in the course of one week, 60 of the inmates, or nearly 22 per cent of the entire number, were carried off, while almost every one of the survivors suffered more or less severely from cholera or diarrhœa. Among the fatal cases were those of 25 girls and 9 boys; and the comparative immunity of the latter, notwithstanding the yet more limited dimensions of their school-room, affords a remarkable confirmation of the general doctrine here advanced; for we learn that, although "good and obedient in other respects, they could not be kept from breaking the windows," so that many of them probably owed their lives to the better ventilation thus established. Now in the Gaol of the same town, in which every prisoner is allowed from 819 to 935 cubic feet of air, and this is continually being renewed by an efficient system of ventilation, there was not the slightest indication of the epidemic influence (Op. cit., pp. 37 and 71).—The other case to be here cited, is that of Millbank Prison, in which the good effects of the diminution of previous overcrowding were extremely marked. In the month of July, 1849, when the epidemic was becoming general and severe in the Metropolis (especially in the low ill-drained parts on both sides of the river, in the midst of which this prison is situated), the number of *male* prisoners was reduced, by the transfer of a large proportion of them to Shorncliff barracks, from 1039 to 402; the number of *female* prisoners, on the other hand, not only underwent no reduction, but was augmented from 120 to 131. Now the general mortality of London, which was 0·9 in 1000 in June and July, *increased* to 4·5 in 1000 in August and September; and the mortality among the *female* prisoners underwent a similar *increase*, from 8·3 to 53·4 per 1000; but the mortality among the *male* prisoners exhibited the extraordinary *diminution*, from 23·1 per 1000, which was its rate during June and July when the

supplied with air, which causes a deposit of soot and various empyreumatic products, that a set of acids have been found by Städeler in the urine of the cow, bearing a remarkable analogy to well-known products of destructive distillation, and one of them actually identical with the *carbolic acid* previously known as one of the ingredients of smoke.—See Prof. Gregory's "Handbook of Organic Chemistry," p. 450.

prison was crowded, to 9·9 per 1000, which was its rate during August and September after the reduction had taken place (Op. cit., App. B., p. 67). It is scarcely possible to imagine a more *probative* case than this; since it shows, in the first place, the marked influence of the crowded state of the prison upon the fatality of the disease,—the diminution of mortality consequent upon the relief of the overcrowding, notwithstanding the augmented potency of the epidemic influence, as indicated by the quintupling of the general mortality of the Metropolis,—and the yet greater increase of mortality among the female prisoners, which proved that the diminution among the males could not be attributed to any recession of the epidemic influence from the locality.

579. The cholera-experience of the Indian army is fertile in examples of the same kind, whose peculiar character makes them even more remarkable. It is to be remembered that the normal amount of Respiration is much lower in a hot than in a temperate climate (§ 564, *a*); consequently any deficiency of oxygenation will tend in a yet higher degree to promote the accumulation of putrescent matter in the system, and this especially when there has been any unusual source of 'waste,' such as that induced by excessive muscular exertion.—The circumstances attendant upon the outbreak of Cholera, in 1846, at Kurrachee in Scinde, in which *ten per cent* of an army of 6380 men were carried off, place the influence of these conditions in a very striking point of view. In order that the comparison may be fairly made, the data will be taken only from European regiments, similar to each other in diet, clothing, regimen, habits, and every other conceivable particular, save such as will be mentioned. Out of 200 Officers, there were only 3 deaths from Cholera (only 1 of these being in an uncomplicated case), or at the rate of 15 per 1000. The 2nd Troop of Horse Brigade, 135 strong, lost 5 men, or at the rate of 37 per 1000. The 60th Rifles, 980 strong, lost 75 men, or at the rate of 76·5 per 1000. Four Batteries of Artillery, 375 strong, lost 37 men, or 96·6 per 1000. The Bombay Fusiliers, 764 strong, lost 83 men, or 108·6 per 1000. And the 86th Regiment, 1091 strong, lost 238 men, or 218 per 1000. Among 42 ladies (wives and families of officers), there was not a single case of cholera. But among 159 soldiers' wives, there were 23 deaths, or 144·6 per 1000. Now most of the Officers, and all the ladies, were quartered in well-ventilated apartments; and the only predisposing cause from which the former could be considered as liable to suffer, was the exposure, in common with the soldiers, to the burning heat during the hours of drill. Of the 9 officers attacked with cholera, 4 belonged to the Bombay Fusiliers, and had been living (like their men) in tents. The Horse Brigade were lodged in good barracks, but had recently come off a march of 1000 miles; being mounted, however, they must have suffered comparatively little fatigue from this. The 60th Rifles were quartered in barracks; but the ventilation of these was very imperfect, and the men were much crowded. The battalions of Artillery were quartered in good barracks; but three out of the four had recently made the march of 1000 miles on foot. The Bombay Fusiliers were quartered in tents, whose accommodation was so limited that 10 or 12 men were cooped up in a space 14 feet square, with the thermometer ranging from 96° to 100°, without any adequate provision for ventilation. The 86th Regiment was quartered in precisely the same manner; and

had recently made the march of 1000 miles under very unfavourable circumstances, besides having previously suffered from the debilitating influence of severe service. The condition of the soldiers' wives as regards their accommodation would be the same as that of their husbands, but they would not be subjected to the fatigue and exposure of drill; on the other hand, their fatigue and exposure during a march would be scarcely inferior to that of the men; and it was among the women, as among the soldiers, of the 86th Regiment, that the chief mortality occurred, their loss having been 1 in 6, or 166·6 per 1000. Now if we arrange these several divisions in a tabular form, we shall see how very closely their respective rates of mortality correspond with the separate or concurrent influence of the different *factors* here enumerated.

| Designation. | Strength. | Deaths. | Deaths per 1000. | Exposure at Drill, &c. | Provision for Respiration. | Previous exertion. |
|---|---|---|---|---|---|---|
| Officers' Ladies . | 42 | 0 | 0 | Nil | Good | Nil. |
| Officers . . | 200 | 3 | 15 | Ordinary | Mostly good | Nil or slight. |
| Horse Brigade . | 135 | 5 | 37 | Ordinary | Good | Moderate. |
| 60th Rifles . | 980 | 75 | 76·5 | Ordinary | Bad | Nil. |
| Artillery . . | 375 | 37 | 96·6 | Ordinary | Good | Severe. |
| Bombay Fusiliers | 764 | 83 | 108·6 | Ordinary | Very bad | Nil. |
| Soldiers' Wives . | 159 | 23 | 144·6 | Nil | Mostly very bad | Partly severe. |
| Do. of 86th Regt. | — | — | 166·6 | Nil | Very bad | Very severe. |
| 86th Regiment . | 1091 | 238 | 218 | Ordinary | Very bad | Very severe. |
| | 3746 | 464 | 124 | | | |

Thus we see that the *highest* rate of mortality presents itself where the three causes were in concurrent action; the *absence* of mortality, where neither of them was in operation. The difference between the mortality of the Bombay Fusiliers (108·6 per 1000) and that of the 86th Regiment (218 per 1000), which were under precisely the same conditions as regards exposure and ventilation, showed the extraordinary influence of previous exertion; but that this would not of itself account for the high rate of mortality in the 86th, is shown by the smaller proportion of deaths in the Artillery; the influence of the same march upon three out of its four battalions, having been in a great degree kept down by the adequate provision for their respiration, so that their mortality was less than that of the 60th Rifles, who had not suffered from previous exertion, but were over-crowded in ill-ventilated barracks.—It is scarcely possible to imagine any more satisfactory proof of the *preventibility* of a large part of this terrible mortality, than is afforded by the analysis of this case;* but if any confirmation be required, it is afforded by the case of Bellary, a fortress about 250 miles north-west of Madras. Although by no means unhealthily situated, this station was not free from Cholera for a single year between 1818 and 1844; and violent outbreaks took place occasionally, such as that of 1839, in which the 39th Regiment was reduced in five months from 735 men to 645, the number of deaths being 90, or $122\frac{1}{2}$ per 1000. The barrack-accommodation in this fort was extremely

* For a fuller statement of it, see the "Brit. and For. Med.-Chir. Rev.," vol. ii. pp. 81-89.

insufficient; and small as it was, it was occasionally encroached-upon still further by the introduction of troops upon their march, in addition to the regular garrison. Every such occasion of overcrowding was shortly followed by a large increase in mortality.* But since the barrack-accommodation has been improved, the troops quartered at Bellary have ceased to suffer from cholera in any exceptional degree, and the ordinary rate of mortality has been considerably diminished.

580. The only condition of atmosphere which can be compared with that arising from overcrowding, in its effect upon the spread of Cholera, is that produced by the diffusion of the effluvia of drains, sewers, slaughter-houses, manure-manufactories, &c., which correspond closely in their nature and effects with the putrescent emanations from the living human body. So remarkably was the localization of the disease connected with this condition, that the knowledge of the existence of the latter rendered it quite safe to predict the former; such predictions being scarcely ever falsified by the result.—As a characteristic illustration of the operation of this cause, the outbreak of Cholera at Albion Terrace, Wandsworth-road, may be specially referred to. This place consisted of 17 houses, having the appearance of commodious comfortable dwellings; the population does not seem to have averaged more than 7 individuals per house, so that there was no overcrowding; yet out of the total 119 or 120, no fewer than 42 persons were attacked with cholera, of whom 30 (or 25 per cent.) died. It was not difficult to account for this fearful result, when the circumstances of the case were inquired into. About 200 yards in the rear of the terrace was an open sewer, whose effluvia were most offensive at the backs of these houses, whenever the wind wafted them in that direction; and the drainage of the houses themselves was so bad, that a stench was continually perceived to arise from different parts of the kitchen floor, and more especially from the back-kitchen. Moreover, in the house in which the first case of cholera occurred, there was an enormous accumulation of most offensive rubbish, exhaling a putrid effluvium. And there was also reason to believe that the water supplied to some of the houses accidentally became contaminated with the contents of a sewer and cess-pool.†—The accumulation of night-soil and other rubbish in a triangular space of about three acres in Witham, a suburb of Hull, had been represented to the local authorities as almost certain to induce a severe outbreak of cholera in the neighbourhood; the prediction was disregarded; but it was most fearfully verified by the occurrence of no fewer than 91 deaths in its immediate neighbourhood.‡—Numerous examples of the same kind might be cited; but the following shows the efficacy of preventive measures. The Coldbath-fields House of Correction, situated in the neighbourhood of some of the most overcrowded and ill-drained parts of the metropolis, had suffered severely from Cholera in the epidemic of 1832-3; for out of 1148 prisoners, 207 were attacked with cholera, of whom 45 died, and 319 more suffered from diarrhœa. At that time, however, it was discovered that the whole drainage of the prison was in a most defective state, and steps were taken to have it completely

* See Mr. Rogers's "Report on Asiatic Cholera in Regiments of the Madras Army, from 1822 to 1844."

† "Report of the General Board of Health on the Epidemic Cholera of 1848-9," p. 43.

‡ Op. cit., p. 45.

and effectually renewed; at the same time the diet was somewhat improved, and more attention paid to temperature and ventilation. In the epidemic of 1848-9, with 1100 prisoners, there was not a single case of cholera in this prison, although the disease was raging in its vicinity; and the cases of diarrhœa were few in number, and were mild in their character.*

581. Now although the Cholera-epidemics have been here referred-to, as affording the most remarkable examples of the influence of a contaminated atmosphere in predisposing the individuals habitually living in it to the invasion of Zymotic disease, yet the evidence is not less strong in regard to the uniform prevalence of ordinary Fevers, &c., in the same localities; the places in which Cholera was the most severe having been almost invariably known as 'fever-nests' at other periods, and being distinguished by a very high rate of mortality. Thus the average age of all persons who die in Witham is only 18 years; whilst the average age at death in the town of Hull (itself distinguished by an unusual brevity of life) is 23 years.—In the 'Potteries' at Kensington, a locality in which filth and overcrowding prevail to an almost unequalled degree, the mortality for three years previously to the invasion of cholera had been such, that the average age at death was only 11 yrs. 7 mo.; and in the first 10 months of 1849, out of a population of about 1000, there were 50 deaths, of which 21 were from cholera and diarrhœa, and 29 from typhus fever and other diseases. It is illustrative of the common points between cholera and other zymotic diseases, that the former appeared there not only in the same streets and in the same houses, but even in the same rooms, which had been again and again visited by typhus; and there were several tenants of such rooms who recovered from fever in the spring, to fall victims to cholera in the summer. Subsequently to this epidemic, the average age at death has been further reduced, by an increase of infantile mortality, to as low as 10 years.—By way of contrast it may be stated that in one of the "Model Lodging-Houses," containing about 550 inmates, among whom was an unusually large proportion of children, the rate of mortality during the three years ending May, 1851 (including the whole period of the cholera-epidemic), was scarcely more than 20 in 1000; the proportion of deaths under ten years of age was only half that of the metropolis in general; there was not a single attack of cholera, and there were only a few cases of choleraic diarrhœa, although the disease was raging in the immediate vicinity; and from the time that the sewerage had been put into complete order, typhus fever had entirely disappeared, a few cases having occurred soon after the opening of the buildings, which were distinctly traceable to a defect in the drainage.†—The following case may be added, in proof of the potency of an atmosphere charged with putrescent emanations, in rendering the system liable to the attacks of Zymotic diseases of various kinds. A manufactory of artificial manure formerly existed immediately opposite Christchurch workhouse, Spitalfields, which building was occupied by about 400 children, with a few adult paupers. Whenever the works were actively carried on, particularly when the wind

* Op. cit., App. B, p. 68.

† "Report on Cholera," App. B, pp. 48 and 77; and Mr. Grainger's subsequent "Report on the present state of certain parts of the Metropolis, and on the Model Lodging-Houses of London," pp. 29, 36.

blew in the direction of the house, there were produced numerous cases of fever, of an intractable and typhoid form; a typhoid tendency was also observed in measles, small-pox, and other infantile diseases, and for some time there prevailed a most unmanageable and fatal form of aphthæ of the mouth, ending in gangrene. From this last cause alone, 12 deaths took place among the infants in one quarter. In the month of December, 1848, when cholera had already occurred in the neighbourhood, 60 of the children in the workhouse were suddenly seized with violent diarrhœa in the early morning. The proprietor was compelled to close his establishment, and the children returned to their ordinary health. Five months afterwards, the works were recommenced; in a day or two subsequently, the wind blowing from the manufactory, a most powerful stench pervaded the building. In the night following, 45 of the boys, whose dormitories directly faced the manufactory, were again suddenly seized with severe diarrhœa; whilst the girls, whose dormitories were in a more distant part, and faced in another direction, escaped. The manufactory having been again suppressed, there was no subsequent return of diarrhœa.*

582. It may not be amiss to add a few examples drawn from the experience which our Indian possessions have afforded, of the influence of an insufficient supply of pure air upon the ordinary mortality in our army and among the people under our control.—There are various military stations which have lain under a most ill-deserved repute for unhealthiness, in consequence of the very imperfect barrack-accommodation afforded to the troops quartered in them. Thus at Secunderabad, in the Madras command, the average annual mortality for the fifteen years previous to 1846-7 was 75 per 1000; this being *nearly double* the average of the whole presidency, and *more than double* that of the remainder of the stations. Now the complaints made year after year, by the medical officers of the troops which have been successively quartered at this station, leave no room for doubt as to the chief cause of this excess; for the regiments of the line quartered at Secunderabad have been always crowded in barracks quite insufficient for their accommodation, one-third of the men having been obliged to sleep in the verandahs, and the remainder getting by no means a due allowance of fresh air; whilst, on the other hand, the officers of these very regiments, who are better accommodated, and the detachment of artillery quartered in more roomy barracks at no great distance, have never participated in this unusual mortality, thereby clearly showing the absence of any special causes of disease at this station, which might not be easily removed.† — The Barrackpore station, in the Bengal command, is even worse than the foregoing, for every regiment quartered there seems to suffer an almost

* "Report on Cholera," p. 42.

† It is a remarkable confirmation of the view formerly stated (§ 411), as to the tendency of the habitual use of Alcoholic liquors to induce a 'fermentible' condition of the blood, by obstructing the elimination of effete matters by the respiratory process (§ 564, *i*), that when the 84th Regt., which is distinguished for its sobriety, was quartered at Secunderabad in 1847–8, it lost only 39 men out of 1139, or 34·2 per 1000, the average mortality of the other stations in the Presidency being about the same as usual. On the other hand, the 63rd Regt., which was far from deserving a reputation for temperance, had lost 73 men during the first nine months of the preceding year, or at the rate of 78·8 per 1000 during the entire year.—All the facts here stated in regard to Secunderabad, have been obtained by the Author direct from the Army Medical Returns.

complete *decimation* annually. Yet there is ample evidence that here also the chief fault lies in the barrack-accommodation.—But one of the most terrible instances of the continuance of a high rate of mortality, which is almost entirely attributable to an insufficient supply of air, is that which is furnished by the Gaols under British control in India. In these are usually confined no fewer than 40,000 prisoners, chiefly natives; and the average annual mortality of the whole was recently 10 per cent, rising in some cases to 26 per cent, or more than *one in four*. This is easily accounted-for, when it is known that in no case is there an allowance of more than 300 cubic feet of air-space for each individual, whilst in some instances 70 cubic feet is the miserable average! *

583. One more set of cases will be cited, as showing the marked effect of the habitual respiration of a contaminated atmosphere, not merely in engendering a liability to zymotic disease, but in directly producing a special form of infantile disease, of the most fearful nature.—The dwellings of the great bulk of the population of Iceland seem as if constructed for the express purpose of poisoning the air which they contain. They are small and low, without any direct provision for ventilation, the door serving alike as window and chimney; the walls and roof let-in the rain, which the floor, chiefly composed of hardened sheep-dung, sucks up; the same room generally serves for all the uses of the whole family, and not only for the human part of it, but frequently also for the sheep, which are thus housed during the severer part of the winter. The fuel employed in the country districts chiefly consists of cow-dung and sheep-dung, caked and dried; and near the sea-coast, of the bones and refuse of fish and sea-fowl; producing a stench, which, to those unaccustomed to it, is completely insupportable. In addition to this, it may be mentioned that the people are noted for their extreme want of personal cleanliness; the same garments (chiefly of black flannel) being worn for months without being even taken off at night. Such an assemblage of unfavourable conditions, combined with the cold damp nature of the climate, might have been expected to induce tubercular diseases of various kinds; but from these the Icelanders appear to enjoy a special exemption (§ 404, III.). Syphilis, also, is wanting, or nearly so; and yet, notwithstanding that the number of births is fully equal to the usual average, the population is stationary, and in some parts actually diminishing. This is partly due to the extent and fatality of the epidemic diseases, of which some one or other spreads through the island nearly every year; but it is chiefly owing to the extraordinary mortality of infants from *Trismus nascentium*, which carries off a large proportion of them between the fifth and the twelfth days after their birth. It is in the little island of Westmannoe and the opposite parts of the coast of Iceland, where the bird-fuel is used all the year round, instead of (as elsewhere) during a few months only, that this disease is most fatal; the average mortality, for the last twenty years, during the first twelve days of infantile life, being no less than 64 per cent, or nearly *two out of three*.†—Now it is not a little remarkable that the very same disease should have prevailed, under conditions almost

* Dr. Mackinnon's "Treatise on the Public Health, &c., of Bengal," Cawnpore, 1848, chap. 1.

† See "Island undersögt fra lægevidenskabeligt Synspunct." Af P. A. Schleisner, M.D. —Copenhagen, 1849.

identically the same, in the island of St. Kilda, one of the Western Hebrides; the state of which was made known by Mr. Maclean, who visited it in 1838. The population of this island, too, was diminishing rather than increasing, in consequence of the enormous infantile mortality; *four out of every five* dying, from Trismus nascentium, between the eighth and twelfth days of their existence. The great if not the only cause of this mortality, was the contamination of the atmosphere by the filth amidst which the people lived. Their huts, like those of the Icelanders, were small, low-roofed, and without windows; and were used during the winter as stores for the collection of manure, which was carefully laid-out upon the floor, and trodden under foot to the depth of several feet. On the other hand, the clergyman, who lived exactly as did those around him, except as to the condition of his house, had brought up a family of four children in perfect health; whereas, according to the average mortality around him, at least three out of the four would have been dead within the first fortnight.—Of the degree in which this fearful disease is dependent upon impurity of the atmosphere, and is preventible by adequate ventilation, abundant proof is afforded by the experience of Hospitals and Workhouses in our own country. Thus in the Dublin Lying-in Hospital, up to the year 1782, the mortality within the first fortnight, almost entirely from Trismus nascentium, was 1 in every 6 children born. The adoption, under the direction of Dr. Joseph Clarke, of an improved system of ventilation, reduced the proportion of deaths from this cause to 1 in 19½. And further improvements in ventilation, with increased attention to cleanliness, during the seven years in which Dr. Collins was Master of this Institution, reduced the number of deaths from this disease to no more than three or four yearly.*—A similar amelioration took place about a century ago, in the condition of the London Workhouses, in which 23 out of 24 infants had previously died within the first year, and a large proportion of these within the first month; for owing to a parliamentary inquiry which was called forth by this fearful state of things, the proportion of deaths was speedily reduced (chiefly by improvement in ventilation) from 2600 to 450 annually.

584. Thus it appears that in all climates, and under all conditions of life, the purity of the atmosphere habitually respired is essential to the maintenance of that power of resisting disease, which, even more than the habitual state of health, is a measure of the real vigour of the system. For, owing to the extraordinary capability which the human body possesses of accommodating itself to circumstances, it not unfrequently happens that individuals continue for years to breathe a most unwholesome atmosphere, without apparently suffering from it; and thus, when they at last succumb to some Epidemic disease, their death is attributed solely to the latter; the previous preparation of their bodies for the reception and development of the zymotic poison, being altogether overlooked. It is impossible, however, for any one who carefully examines the evidence, to hesitate for a moment in the conclusion, that the fatality of epidemics is almost invariably in precise proportion to the degree in which an impure atmosphere has been habitually respired; that an atmosphere loaded with putrescent miasmata may afford a *nidus* wherein a zymotic poison under-

* See Dr. Collins's "Practical Treatise on Midwifery," p. 513.

goes a marked increase in quantity and intensity, the putrescent exhalations from the lungs and skin of the living subject being at least as effectual in furnishing such a 'nidus,' as are the emanations from fæcal discharges or from other decomposing matters; that the habitual respiration of such an atmosphere tends to induce a condition of the blood, which renders it peculiarly susceptible of perversion by the introduction of zymotic poisons, and which favours their multiplication within the system;* and lastly, that by due attention to the various means of promoting atmospheric purity, and especially to efficient ventilation and sewerage, the rate of mortality may be enormously decreased, the amount and severity of sickness lowered in at least an equal proportion, and the fatality of epidemics almost completely annihilated. And it cannot be too strongly borne in mind, that the efficacy of such *preventive* measures has been most fully substantiated, in regard to many of the very diseases in which the *curative* power of Medical treatment has seemed most doubtful; as, for example, in Cholera and Malignant Fevers.

# CHAPTER XI.

## OF NUTRITION.

### 1.—*General Considerations.—Formative Power of Individual Parts.*

585. The function of Nutrition, considered in the widest acceptation of the term, includes the whole series of operations, by which the alimentary materials,—prepared by the Digestive process, introduced into the system by Absorption, and carried into its penetralia by the Circulation,—are converted into Organized tissue; but in a more limited sense it may be understood as referring to the last of these operations only, that of *Histogenesis* or tissue-formation, to which all the other organic functions, in so far as they are concerned in maintaining the life of the individual, are subservient, by preparing and keeping in the requisite state of purity the materials at the expense of which it takes place. It has been shown in the earlier portion of this volume, that every integral part of the living body possesses a certain capacity for growth and development, in virtue of which it passes through a series of successive phases, under the influence of the steady heat, which in the warm-blooded animal is constantly acting upon it (CHAP. III., SECT. 1, 2); this capacity being an endowment which it derives by direct descent from the original germ, but undergoing a gradual diminution with the advance of life, until the power of *maintenance* is no longer adequate to antagonize the forces that tend to the *disintegration* of the system (CHAP. III., SECT. 3). It has been also shown,

* A careful consideration of the very satisfactory evidence which has been of late years collected on this point, must (in the Author's opinion) satisfy any *competent* and *unprejudiced* inquirer, that Endemic Fevers, originating in local causes (marsh miasmata and the like), and affecting those only who are exposed to such causes, may find, by the crowding-together of infected subjects, a *nidus* for development within the Human system; so that these diseases *then* become communicable by human intercourse, although not so originally.—For a discussion of this subject, see the Articles on 'Yellow Fever' in the "Brit. and For. Med.-Chir. Rev., vols. i. and iv.

that notwithstanding the diversities in the structure and composition of the several tissues, the Blood supplies the materials which each requires; every tissue possessing (so to speak) an *elective affinity* for some particular constituents of that fluid, in virtue of which it abstracts them from it, and appropriates them to its own uses.—But it has been shown, on the other hand, that the 'formative capacity' does not exist in the tissues alone, but is shared by the Blood, which must itself be regarded as deriving it from the original germ; for there are certain simple kinds of tissue, which seem to take their origin directly in its plastic components (§§ 26—29). Of others which cannot be said thus to originate in the blood, the development is entirely determined by the quantity of their special *pabula* which it may contain (§ 120). And even of those tissues which must be considered as most independent and self-sustaining, the development is not only checked by the want of a due supply of their appropriate materials, but it is modified in a very remarkable degree by the presence of abnormal substances in the blood, which single-out particular parts, and effect determinate alterations in their nutrition, in such a constant manner as to show the existence of a peculiar 'elective affinity' between them (§ 201).—In so far, then, as the process of Nutrition is dependent upon the due supply and normal state of the Blood, its conditions have been already sufficiently discussed; and we have now only to consider it in its relations to the Tissues.

586. The demand for Nutrition primarily arises from the tendency of the organism to simple *increase* or *growth*. Of this we have the most characteristic illustration in the multiplication of the first embryonic cell, by the simple process of 'duplicative subdivision' (§ 104); whereby a multitude of cells is produced, every one of which is similar in all essential particulars to the original. But after the different parts of this homogeneous embryonic mass have taken upon themselves their respective modes of development, so as to generate a diversity of tissues and organs, each one of these continues to increase after its own plan; and thus the child becomes the adult, with comparatively little change but that of growth. An excess of growth, taking place conformably to the normal plan of the tissue or organ, constitutes *Hypertrophy;* whilst a diminution, without degeneration or alteration of structure, is that which is properly distinguished as *Atrophy.*—But Growth is not confined to the period of increase of the body generally; for it may manifest itself in particular organs or tissues, as a normal operation, at any subsequent part of life. Thus when there is an extraordinary demand for the functional activity of a particular set of Muscles, it is supplied by an increase in the amount of their contractile tissue (§ 312); or if one of the Kidneys be disabled from performing its office, the other may be rendered capable of fulfilling it, by an augmented production of its own secretory tissue; or if there be an excess of fatty matters in the blood, they may be eliminated by an augmentation of the Adipose tissue throughout the body.—And further, even where there is no such manifestation of increase, there is really a continual growth in all the tissues actively concerned in the vital operations, and this even to the very end of life; although it may be so far counterbalanced, or even surpassed, by changes of an opposite kind, that instead of augmentation in bulk, there is absolute diminution.

587. The evolution of the complete organism from its germ, however,

does not consist in mere growth; for by such a process nothing would be produced but an enormous aggregation of simple cells, possessing little or no mutual dependence, like those which constitute the shapeless masses of the lowest Algæ. In addition to increase, there must be *development*, that is, a passage to a higher condition, both of form and structure, so that the part in which this change takes place becomes fitted for some special function, and is advanced towards the state in which it exists in the highest or most completed form of its specific type. Thus the development of *tissue* consists in the change from a simple mass of cells or fibres into any other form; as in the production of dentine from the cellular substance of the tooth-pulp (§ 279), or in the formation of bone in the sub-periosteal membrane (§ 267). So, again, the developmental change is seen in the passage of an entire *organ* from a lower to a higher condition, by the evolution of new parts, or by a change in the relations of those already existing, even though the change in its texture should consist of little else than of simple increase; thus in the development of the heart, we have the original single cavity subdived, first into two, and at last into four chambers; and in the development of the brain we find the sensory ganglia to be the parts first formed, the anterior lobes of the cerebrum to be evolved (as it were) from these, the middle lobes sprouting-forth from the back of the anterior, and the posterior from the back of the middle; yet with all this, there is no production of any new kind of tissue, the new parts being generated at the expense of histological components identical with those of the pre-existing.—Now it is in the early period of embryonic life, that the *developmental* process is most remarkably displayed; for it is then that we see that transformation of the primordial cells into tissues of various kinds, which originates a special *nisus* in each part, whereby the production of the same tissue in continuity with that first-formed, comes to be a simple act of growth; and it is then also that we observe that marking-out of all the principal organs, by the development of tissue in particular directions, which makes all subsequent evolution but a completion or filling-up of the plan thus sketched-out. Thus during the first few days of incubation in the Chick, the foundation is laid of the vertebral column, the nervous centres, the organs of sense, the heart and circulating system, the alimentary canal, the respiratory apparatus, the liver, the kidneys, and of many other parts; and at the termination of that period, the chick emerges in such a state of completeness of development, that little else than increase is wanting, save in the plumage and sexual organs, to raise it to its perfect type. The same may be said of the Human organism; save that the period of its development is relatively longer, in accordance with the higher grade which it is ultimately to attain; its earliest stages being passed-through, however, with extraordinary rapidity. The completer evolution of the generative organs, of the osseous skeleton, and of the teeth, constitute the principal developmental changes which the Human organism undergoes in its progress from the infantile to the adult condition; almost every other alteration consisting in simple increase of its several component tissues and organs, without any essential change in their form or structure. And when the adult type has been once completely attained, every subsequent change is one rather of degeneration than of development, of retrogression rather than of advance.

588. The difference between the two processes of Growth and Development is most characteristically shown in those cases, in which there is a partial or complete arrest of one of them, without any corresponding impairment of the other. Thus a dwarf, however small in stature, may present a perfect development of every part that is characteristic of the complete human organism; the deficiency being solely in the capacity for *growth.* On the other hand, the usual size at birth may be attained, and every organ may present its ordinary dimensions, and yet some important part may be found in a condition of *arrested development;* thus the heart may consist of but a single cavity, or the interventricular or interauricular septa may be incomplete, so that it has not passed beyond the grade of development which it had attained at an early period of embryonic life, although its growth may have continued; or the brain may in like manner exhibit a deficiency of the posterior lobes, or of the corpus callosum, or of some other part whose formation normally takes place in the latter months of intra-uterine life, although the parts already produced may have continued to grow at their usual rate.—Numerous instances of the same kind might be cited, but these must suffice.

589. The demand for Nutrition arises, however, not merely from the exercise of the formative powers which are concerned in the building-up of the organism, but also from the degeneration and decay which are continually taking place in almost every part of it, and the effects of which, if not antagonized, would speedily show themselves in its complete disintegration. We have seen (§ 114) that as each component cell of the organism has to a certain degree an independent life of its own, so has it also a limited duration; and that its duration usually bears an inverse ratio to its functional activity. This is particularly striking, when we compare the ratio of change in the organisms of cold-blooded animals at low and at high temperatures; for they live slowly, need little nutriment, give off but a small amount of excretory products, and require a long time for the performance of the reparative processes, under the former condition; but live fast, require a comparatively large supply of nutriment, give off a far greater amount of carbonic acid and other compounds resulting from the 'waste' of tissue, and exhibit a far more rapid reparation of injuries, in the latter state. The constantly high temperature of Man, as of other warm-blooded animals, prevents this difference from being displayed in him in a similar manner; but it is well seen when we contrast his different tissues with each other, and study their respective histories. For whilst there are some which appear to pass through all their stages of growth, maturation, and decline, within a limited period, there are others whose existence seems capable of almost indefinite prolongation, and others, again, which are liable to have a period put to it at any time, by the direction of their vital force into other channels. —Of those belonging to the first category, a characteristic example is presented by the ovule; which, if not fertilized within a limited period after its maturation, speedily declines and decays; and the same law of limited duration doubtless extends to a large proportion of such tissues as are actively concerned in the maintenance of the organic functions, as for example, the corpuscles of the blood (§ 148), the epithelial cells of mucous membranes, which minister to absorption in one situation (§ 461) and to secretion in another (§ 235), the cells forming the parenchyma of

the ductless glands (§ 482, IV.), and many others.—The contrary extreme to this may be found in those tissues, whose functions are rather physical than vital; and especially in such as undergo consolidation by the deposit of solidifying matter, either in combination with the animal membrane or fibre, or in its interstices. Such tissues are withdrawn from the general current of vital action, and there seems to be no definite limit to their duration, except such as is imposed by the chemical and mechanical degradation to which they are subjected. This appears to be the case with the simple fibrous tissues, especially by the yellow, even in their soft or unconsolidated state; but it is far more obvious in the osseous substance, which is chiefly formed by the combination of calcareous salts with the fibrous animal basis. So, again, in the dentine and enamel of teeth, we have examples of tissues that have once undergone a similar consolidation, retaining their condition unchanged through the whole remainder of life, under circumstances which show that if any nutritive change take place in them, its amount must be extremely small. Yet it is curious to observe, that both in the osseous and dentinal structures of the young, there is obviously a determinate limit of existence; as is shown in the rapid disappearance of a considerable part of the lamellæ first formed in the cartilaginous matrix (§ 265), as also in the death and removal which continue to take place in the inner and older portions of the shaft of a round bone during the whole period of its increase (§ 267); and in the exuviation, at a certain definite epoch, of the first set of teeth, which exuviation is usually preceded by the death and disintegration of their own texture (§ 289). In hair, nails, and other epidermic appendages, which, when once their component cells have undergone consolidation by the deposit of horny matter in their interior, may remain unchanged for centuries, we must recognise the same principle of indefinite duration, in connection with the annihilation of vital activity; the chemical constitution of these substances, moreover, being such as renders them but little prone to be acted-upon by ordinary decomposing agencies.—In the case of the Muscular and Nervous tissues, however, we trace the operation of causes that differ from any of those already specified. These tissues are doubtless subject, like all others that are distinguished by their vital activity, to the law of limited duration; for we find that, when not called into use, they undergo a gradual disintegration or wasting, which is not adequately repaired by the nutritive processes (§§ 313, 347). But their existence as living structures appears to be terminable at any time, by the exercise of their functional powers; for the development of muscular contractility or of nervous force seems to involve, as its necessary condition, the metamorphosis (so to speak) of the vital power which was previously exercising itself in the nutritive operations; and the materials of these tissues, now reduced to the condition of dead matter, undergo those regressive changes which speedily convert them into excrementitious products. But the very manifestation of their peculiar vital endowments, determines an afflux of blood towards the parts thus called into special activity; and from this it comes to pass that the nutrition of these textures is promoted, instead of being impaired, by the losses to which they are thus subjected; so that their constant exercise occasions an augmentation, rather than a diminution, of their substance,—a due supply of the requisite materials being always pre-supposed.

590. Thus it comes to pass, that during the whole period of active life, a demand for Nutrition is created by every exertion of the vital powers, but more especially by the evolution of the Nervous and Muscular forces. The production and application of these, indeed, may be considered as the great end and aim of the Human organism, so far at least as the individual is concerned; the whole apparatus of Organic life being subservient to the building-up and maintenance of the Nervo-muscular apparatus, and of those parts of the fabric (*e.g.* the bones, cartilages, fibrous textures, &c.) which it uses as its mechanical instruments. Thus the activity of all the organic operations, when once the full measure of growth has been attained, is mainly determined by that of the animal functions; and as the 'rate of life' of all the parts which minister to the former, will be in proportion to the energy with which they are called-upon to perform their functions, their duration will diminish in the same proportion, and hence occasion will arise for their continual renewal.* But since, in the attainment of the adult condition, the germinal capacity has undergone a gradual diminution, whilst the exercise of the animal powers has become vastly increased, the formative processes are only capable of *maintaining* the organism in its state of completeness and vigour, by making-good the losses consequent upon the continual disintegration to which it is subjected by its nervo-muscular activity (§ 132). And with the advance of years, the further diminution of the reproductive capacity involves, on the one hand, a progressive decrease in the substance of the tissues and organs most important to life, (their bulk, however, frequently remaining unchanged, or even increasing, in consequence of the accumulation of fat,) and on the other, a gradual weakening of its powers of action (§ 133).

591. The performance of the function of Nutrition, the demand for which arises out of the causes that have been now discussed, is dependent, not merely upon a due supply of pure and well-elaborated blood, but also upon the normal condition of the part to be nourished, and especially upon its possession of a right measure of 'formative capacity;' in virtue of which, the newly-produced tissues are generated in the likeness, as well as in the place, of those which have become effete. The exactness of this replacement is most remarkably shown in the retention of the characteristic form and structure of each separate organ or part of the

* Such an excellent illustration is afforded by the phenomena of Vegetation, of the doctrines here propounded, that it would be scarcely desirable to pass it by in this place, although it has been elsewhere more fully referred-to ("Princ. of Phys., Gen. and Comp.," §§ 494, 554).—The leaves of Plants serve, like the absorbing and assimilating cells of Animals, for the introduction and elaboration of the nutritive materials which are to be applied to the extension of the fabric, the more permanent and inactive parts of which are thus generated at the expense of materials prepared by the vital operations of the more transitory and energetic. Now there is an obvious limit to the duration of the leaf-cells; but this limit is not precisely one of time, being rather dependent upon the completion of their series of vital actions. Thus, although we are accustomed to look upon the 'fall of the leaves' (which is nothing else than an exuviation consequent upon death) as a phenomenon of regular seasonal recurrence, and to regard their replacement by a new growth as occurring at a not less constant interval, yet experience shows that these intervals are entirely regulated by temperature; for if one of the ordinary deciduous trees of temperate climates be transferred to a tropical climate, it will live much faster, its leaves being shed far more frequently, and being replaced much more speedily; so that two, or even three, successive exuviations and reproductions of its foliage may take place within a year.

body, and thus of the entire organism, through a long series of years; no changes being apparent (so long as the state of health is preserved), but such as are conformable to the general type of that alteration which the organism undergoes with the advance of life. And not only is this to be noticed in the conservation of all those distinguishing points of structure which mark the species, and are essential to its well-being; but it is still more remarkably displayed in the continuous renewal of those minor peculiarities, which constitute the characteristic features of the individual, and which serve to distinguish him from his fellows. And how much this depends upon the formative capacity originally derived from the germ, is evident from this, that a similar moulding (so to speak) of the nutritive material takes place, in the first instance, into the form characteristic of the species, and afterwards into that which marks the individual, and that the peculiarities of the individual are frequently such as have been distinctive of one or other of the parents, or present a combination of both. But it is curious that the formative power should often be exercised, not only in maintaining the original type, but also in keeping-up some acquired peculiarity; as, for example, in the perpetuation of a cicatrix left after the healing of a wound. For, as Mr. Paget has remarked, the tissue of a cicatrix grows and assimilates nutrient material, exactly as do its healthy neighbouring tissues; so that a scar which a child might have said to be as long as his own fore-finger, will still be as long as his fore-finger when he becomes a man. And when the mode of nutrition in any part has been altered by disease, there is frequently an obstinate tendency to the perpetuation of the same alteration; or, if the healthy action be for a time restored, there is a peculiar tendency to the renewal of the morbid process in the part; and this is stronger the more frequently it recurs, until at last it becomes inveterately established. There is, however, in the tissues generally, as in the blood (§ 207), a general tendency to a return to the normal type, after it has undergone a temporary perversion; and thus it is that we find the normal structure of parts gradually restored, when the morbid tendency has been overcome; and that even cicatrices and indurations, notwithstanding their usual obstinate persistence, occasionally disappear. The normal type is, perhaps, less likely to be thus recovered, when the departure from it is very slight, and consists rather in the wrong plan (so to speak) on which the new matter is laid down, than in a perversion of the nutritive process itself.

592. Of the mode in which the substitution of new tissue for that which has become effete, is effected in the process of Nutrition, our knowledge is at present limited; but there can be little doubt that it nearly always takes place in a manner closely conformable to the first development of each tissue. In some instances there is an obvious *replacement* of the old and dead by the young and active elements: this is the case, for example, in the constantly-repeated production of the Epidermic and Epithelial layers; for whether they are developed from germs imbedded in the subjacent basement-membrane, or from nuclei formed *de novo* in the blastema on its free surface, or by the duplicative subdivision of pre-existing cells, there is a continual succession of new cells, which take the place of those that are cast off as defunct and useless. So in the growth of Hair, the increase of which takes place only at its base, we can trace at any period the same development of newly-formed spheroidal cells into horny fusi-

form fibres, as that which took place when first the hair began to sprout from the aggregation of epidermic cells at the bottom of its follicle. So, again, in the vesicular tissue which constitutes the essential part of the Nervous centres, there are appearances which indicate that its peculiar cells are in a state of continual development, newly-formed ganglionic vesicles taking the place of those which have undergone disintegration. But there are other textures whose nutrition is more completely *interstitial;* their elements being more closely coherent, and their newly-formed portions being developed throughout the substance of the old, instead of (as in the case of the epidermis and its appendages) *superficially* or in mere continuity with it. Such is the case, for example, with Muscle, the mode of whose nutrition has not yet been elucidated. We can only infer from analogy, that here too each fibre or fibril will pass, in the course of its development, through the same stages which those of the embryo did when its muscles were first formed. And this analogy seems to derive confirmation, from the presence, in all well-nourished muscles, of bodies which bear the appearance of nuclei; for these, as Mr. Paget remarks, "are not the loitering impotent remains of embryonic tissue, but germs or organs of power for new formation." And it is further confirmatory of this view, that losses of substance of muscle, which involve the destruction of these centres of nutrition, are not replaced, like losses of cuticle, by new tissue of the same kind; the power to form it not being inherent in the blood or in the neighbouring parts. Nevertheless it must be admitted that no intermediate stages of development can be traced in the fibres, even of those muscles of the adult which are in most constant use, and of which the nutrition is the most active, that are at all comparable to those which are met with in the muscular tissues of the embryo.—With regard, again, to the interstitial nutrition of Bones and Teeth, we know nothing whatever. That some nutritive change is continually taking place in them, is certain from the fact that if the supply of blood be withdrawn, the parts thus affected die and are cast out of the body; and it is also made apparent by the effects of madder in gradually tinging even the bones and teeth of the adult, though for such a change a much longer period is required in the adult than in the young animal.—The nutrition of the simple Fibrous tissues would also appear to take place interstitially; but there is no proof that the pre-existing tissues are here in any way concerned in their replacement, which probably takes place in virtue of the self-developing powers of the blood itself.

593. Of the modes in which the effete particles of tissues whose term of life has expired, or whose vital energy has been exhausted, are removed and disposed of, our present knowledge is no less imperfect. In the case of those tissues which are *superficially* nourished, a continual loss of substance is obviously taking place by the exuviation of dead particles *en masse;* this is the case with the whole series of Epithelial and Epidermic cells, which are thrown off with little previous change, like the leaves of trees, their decay not taking place, for the most part, until after they have become detached from the organism. But the fact is altogether different with regard to those whose nutrition is *interstitial*, especially the nervous and muscular tissues; for the decomposition of these would seem to occur in their very substance, its products being taken-up by the blood, and subsequently eliminated from it by organs appropriated to that pur-

pose. The evidence of this is seen, as regards Muscle, in the presence of creatine, creatinine, inosite, and other undoubted products of regressive metamorphosis, in the 'juice of flesh;' as regards the Nervous substance, however, no such definite proof can be at present afforded, since its normal constitution has not yet been sufficiently studied to enable the products of its decomposition to be distinguished.—There is one remarkable form of degeneration, however, which is common to nearly all the tissues, and which seems to occur as a normal alteration in many of them at an advanced period of life; this consists in the conversion of their albuminous or gelatinous materials into fat, thus constituting what is known as 'fatty degeneration.' That this change is not due to the removal of the normal components of the tissues, and the substitution of newly-deposited fatty matter in their place, but is (in most cases at least) the result of a real conversion of the one class of substances into the other, has been already pointed out (§ 40). And there are certain facts which indicate that this kind of degeneration is a part of the regular series of processes, by which tissues that have served their purpose in the economy are prepared for being removed by absorption; one of the most remarkable being the observations of Virchow* and Kilian† with regard to the fatty degeneration of the muscular tissue of the uterus after parturition. So, as Mr. Paget has pointed out, the fibrinous and corpuscular products of inflammation are often brought into a state fit for absorption, by passing through this intermediate stage; the fibrinous substance being observed to be dotted by granules, which are known to be oil-particles by their peculiar shining black-edged appearance, and at the same time losing its toughness and elasticity, and being no longer rendered transparent by acetic acid; whilst the lymph-cells present a similar increase of shining black-edged particles like minute oil-drops, which accumulate until they nearly fill the cell-cavity, their nuclei at the same time gradually fading and disappearing.‡ Thus, then, if the fat, which is one of the products of this regressive metamorphosis, be absorbed as fast as it is formed, and the effete tissue be replaced by a new production, which seems to be the case with Muscles in a state of healthy activity, there is no appearance of degeneration, and the nutrition is kept up to its normal standard. But if, from the advance of age, or from the insufficient exercise of the muscles, their nutrition take place less rapidly than their waste, whilst the products of their degeneration are still removed, simple atrophy is the result. If, on the other hand, the general conditions being similar, the fat produced in degeneration be not absorbed, but remain in the tissue (as is, perhaps, most likely to happen when a copious supply of respiratory material is afforded by other substances), an obvious 'fatty degeneration' is the result. —It may be stated as a general rule, that no absorption of the materials of tissues can take place, without a previous degeneration such as this, or a more complete decomposition. There is no evidence that any healthy tissue is ever thus absorbed, or that any preternatural activity of the absorbent vessels can ever (as formerly supposed) be the occasion of a loss of substance; in fact, so long as the vital force is in active operation in a part, and its processes of growth and development are being normally

* "Verhandlungen der Gesellschaft für Geburtshülfe," Berlin, vol. iii. p. xvii.

† "Henlé und Pfeuffer's Zeitschrift," vol. ix. p. 1.

‡ See Mr. Paget's 'Lectures on Inflammation' in "Medical Gazette," 1850, vol. xlv. p. 7.

carried-on, such absorption may be considered to be impossible. On the other hand, if a part die *en masse*, it is not removed by absorption, but becomes isolated by the separation and recedence of the living parts, and is then cast out altogether, even from the interior of the body, as we see in the case of a necrosed bone; its condition being then essentially the same as that of the outer layers of the tegumentary organs, which are cut off, by their distance from a vascular surface, from all further nutrient change. The difference between these two modes of removal is well seen (as Mr. Paget has remarked) in the case of the Teeth; for the fangs of the deciduous teeth undergo degeneration, when the current of nutrition is diverted towards those which are to succeed them, their materials being slowly decomposed so as to become soluble, and being gradually removed by absorption, so that nothing is left at last but the crowns of the teeth; on the other hand, the permanent teeth which are not to be succeeded by others, when no longer receiving their due nutrition, die, and are cast out entire.

594. Among the conditions of healthy Nutrition, a due supply of Nervous power is commonly enumerated; and it cannot be questioned that the want of such a supply is frequently the source of a perversion of the normal operations. This, however, by no means proves that the formative power is derived from the nervous system; and such an idea is at once negatived by a number of incontestable facts. Yet it may be freely admitted that the right direction and application of this power in Nutrition, may sometimes depend upon guidance and direction afforded by the Nervous centres, in the same manner as the Secreting process is capable of being thus influenced; in fact we can scarcely explain in any other mode that influence of mental states upon the nutrient operations, which frequently leads to very important modifications of them.—The whole of this subject, however, will be more appropriately considered hereafter (CHAP. XVII).*

### 2. *Varying Activity of the Nutritive Processes.—Reparative Operations.*

595. Without any change in the *character* of the Nutritive processes, there may be considerable variations in their *degree of activity;* and this, either as regards the entire organism, or individual parts, though most commonly the latter. These variations may be so considerable as to constitute Disease; though there are some which take place as part of the regular series of Physiological phenomena. Thus, as we have seen, it is to the excess of formative activity, that the increase of the organism in the earlier period of life is due, its 'waste' being at the same time extremely rapid; whilst it is to a corresponding reduction in the regenerative power, and not to positive excess of 'waste' or decay (this, indeed, taking place very slowly), that the gradual decline of the organism in advancing years is to be attributed. So also we find that local as well as general variations may take place, as a part of the regular series of vital phenomena; and this during the period of adult life, as well as in the

* In the treatment of this subject, the Author has made free use of the valuable materials contained in Mr. Paget's 'Lectures on Nutrition, Hypertrophy and Atrophy,' ("Med. Gaz.," 1847) which have enabled him, whilst still expressing the same general doctrines as in previous editions, to make great improvements in the exposition and illustration of them.

earlier and later epochs. Thus all those differences in the proportional development of the several parts of the organism, which mark the distinction between the adult and the child, even where (as in the case of a dwarf), there is no difference in stature, result from a decline in the formative capacity of those which are peculiarly adapted to the wants of the earlier stage (the Thymus gland for example), and from an increased activity of nutrition in those which are destined to the use of the adult, the Generative organs more particularly. And the intermittent activity of the sexual apparatus of the female affords a remarkable example of the same principle; this being marked not merely in the enormous development of the uterus and mammary glands as a consequence of conception, but in the periodical change which takes place in the ovaries, whereby the ova are matured and thrown off at certain regular intervals. The decline in the formative power of these same organs, moreover, when as yet the organism in general shows but little indication of deterioration, is another characteristic example of the variation in Nutritive activity resulting from the inherent endowments of the part, and essentially irrespective of the condition of the blood, of the circulation, and of the organism as a whole; but, as formerly shown (§ 203), the production and maintenance of other and apparently unconnected organs are *complementally* dependent upon the formative activity of the generative apparatus.

596. The abnormal excess of Nutritive change which properly constitutes *Hypertrophy*, appears to depend upon a departure from one or other of the conditions, under which, as already specified, the change normally takes place; namely, the right composition of the blood, a due supply of such blood, and a proper formative capacity in the part itself.—Of the excess of nutrition resulting from the presence of an excess of the peculiar materials of certain tissues in the circulating fluid, examples have already been given (§ 120); it is important to remark, however, that although hypertrophy may be thus induced in any of the tissues which constitute the instruments of *organic* life, yet there is no evidence that either the nervous or the muscular apparatus can be forced (so to speak) to an augmentation in bulk by the abundance of their nutritive materials.—With regard, in the next place, to the supply of blood, there can be no doubt that in general an increased flow of blood towards a part is consequent upon, rather than a cause of, an excess in its nutritive activity; but still there are cases in which its causative agency may be traced. Various examples of this have been supplied by the experiments and observations of John Hunter, the records of which are left in his Museum. Thus if the spur of a cock be transplanted from the leg to the comb, which is a part far more vascular than that with which it was originally connected, it undergoes an extraordinary augmentation in size; having in one instance grown in a spiral form, until it was six inches long; and in another curved forwards and downwards like a horn, so that its end needed to be often cut, to enable the bird to bring his beak to the ground in feeding. So, again, it was remarked by Hunter, and has been frequently observed since, that an increased growth of hair often takes place on surfaces to which there is an increased determination of blood as a consequence of inflammation in some neighbouring part, though not from the surface of the inflamed part itself. So it sometimes happens that when an ulcer of the integuments of the leg has long existed in a young

person, the subjacent bone may share in the increased afflux of blood, and may enlarge and elongate. And it seems not improbable that we are to attribute the increased thickness of the cuticle on parts which are exposed to continual pressure or friction, to the augmented afflux of blood which is determined to the irritated surface (§ 241).*—The greater number of cases of Hypertrophy, however, must undoubtedly be referred to the preternatural formative capacity of the part itself; and this may either be congenital or acquired. Of this congenital excess, we have a remarkable example in the abnormal growth of an entire limb, or of fingers or toes,† which cannot with any probability be referred to an original excess in the supply of blood, the enlargement of the arteries leading towards such parts being almost certainly consequent upon their unusually rapid growth, just as in the case of the uterine and mammary arteries of the pregnant female. The most remarkable instances of the acquirement of increased formative activity, are presented to us in that augmented growth of the nervous and muscular tissues, which is consequent upon the exercise of their functional powers. This may be considered as to a certain extent a normal adjustment of the supply to the demand; but there are some instances in which it takes place to such an extent as to become a positive disease. Thus it not unfrequently happens, that if young persons who naturally show precocity of intellect, are encouraged rather than checked in the use of the brain, the increased nutrition of the organ (which grows faster than its bony case) occasions pressure upon its vessels, it becomes indurated and inactive, and fatuity and coma may supervene. Now although in such cases there must probably have been some congenital tendency to preternatural activity of the brain, which manifests itself in precocity of intellect, yet, there is no doubt that this may be augmented by the 'forcing system' of education; whilst, on the other hand, it may be controlled by a system of management adapted to the peculiar circumstances of the case. Excess of muscular development is peculiarly prone to show itself in the involuntary muscles; but this production is in almost every instance the result of the demand for increased muscular exertion, which is consequent upon some obstruction to the usual function of the part. Thus an extraordinary hypertrophy of the muscular coat of the urinary bladder is often seen as a consequence of obstruction to the exit of the urine, through the presence of a stone in the bladder or of a stricture in the urethra; so, again, hypertrophy of the muscular coat of the gall-bladder may take place as a consequence of obstruction of its duct by a gall-stone; hypertrophy of the muscular coat of any part of the alimentary canal may take place in consequence of stricture lower down; and even hypertrophy of the heart is generally, if not always, attributable to obstruction to the exit of the blood which it propels, resulting either from stagnation of the pulmonary circulation by the deficient aeration consequent upon disease of the lungs (in which case

* It is commonly said that local hypertrophy may be induced by long-continued Congestion; but this is not true hypertrophy; for the bulk of the organ is not augmented by the increased production of its normal tissue, but by the addition of tissue of an inferior type of organisation, as in Inflammation (§ 609).

† A case of hypertrophy of an entire limb was described by Dr. John Reid in the "Edinb. Monthly Journ.," 1843, p. 198; and several cases of hypertrophy of the fingers were described by Mr. Curling in the "Med.-Chir. Trans.," vol. xxviii.

the hypertrophy is limited to the right side of the heart), or from thickening or induration of the semilunar valves or narrowing of the orifices of the aorta and pulmonary artery. It is curious, moreover, to observe that hypertrophy of muscles frequently becomes a source of increased nutrition of the bones to which they are attached; this being manifested, not merely in the augmented bulk of the bones of limbs that are specially exercised, but also in the increased prominence of the ridges and processes to which the muscles are attached. This adaptiveness on the part of the formative activity of the osseous tissue, is curiously manifested also in the relation of the skull to the brain; for if the bulk of the brain be not too rapidly augmented, the skull will enlarge accordingly, and this (in some instances) not merely by the extension of its normal bones, but by the intercalation of new osseous elements, the 'ossa wormiana;' whilst, on the other hand, if there be a diminution in the bulk of the brain, the cranium may adapt itself to this also, by a thickening on its internal surface, or concentric hypertrophy,—this change, rather than a diminution in the whole substance of the skull, being more liable to take place in cases in which the cranial sutures have already closed, and the nutrition of the bone has become inactive, so that the modelling process, which consists in the absorption of old and the deposition of new osseous tissue (§ 130), cannot take place.

597. The production of *Tumours* must be considered as a manifestation of an excess of formative activity in individual parts, and as constituting, therefore, a species of Hypertrophy. For a tumour may be composed of the tissues which are normal to the part; as we see especially in the case of those tumours of the uterus, which are made up of an excess of its ordinary muscular and fibrous elements. But, as Mr. Paget has justly remarked, "an essential difference lies in this;—the uterus (often itself hypertrophied) in its growth around the tumour maintains a normal type, though excited to its growth, if we may so speak, by an abnormal stimulus; it exactly imitates, in vascularity and muscular development, the pregnant uterus, and may even acquire the like power; and at length, by contractions like those of parturition, may expel the tumour spontaneously separated. But the tumour imitates in its growth no natural shape or construction; the longer it continues, the greater is its deformity. Neither may we overlook the contrast in respect of purpose, or adaptation to the general welfare of the body, which is as manifest in the increase of the uterus as it is improbable in that of the tumour."* A gradation is established, however, between true Hypertrophies and Tumours, by those productions of glandular tissue, which are made up of the proper substance of the gland with which they are connected, as the mammary, the prostate, or the thyroid, and which (though frequently encysted) are sometimes met with as outlying portions of the gland itself.—There is another class of objects to which Tumours come into close relation, and which must be referred, like them, to a local excess of formative activity; these are the "supernumerary parts" which are not unfrequently developed during fœtal life, as, for example, additional fingers and toes. It seems absurd to refer these, formed as they are by simple outgrowth from the limbs to which they are attached, to the "fusion of germs" which has

* 'Lectures on Tumours,' in "Medical Gazette," 1851, vol. xlvii. p. 925.

been hypothetically invoked to explain more important excesses, as those of additional limbs, double bodies, or double heads; and yet from the lower to the higher form of excess, the transition is so gradual that what is true of the former can scarcely but be true of the latter; so that even complete "double monsters" must be regarded, not as having proceeded from two separate germs which have become partially united in the course of their development, but from a single germ, which, being possessed of an unusual formative capacity, has evolved itself into a structure containing more than the usual number of parts, and comparable to that which may be artificially produced by partial fission of the bodies of many of the lower animals.*—We can scarcely fail to recognize, in this whole series of abnormal productions, the operation of a similar power. In the formation of a supernumerary part, this has been sufficient, not merely to produce the tissues and to develope them according to a regular morphological type, but to impart to the fabric thus generated a separate and even an independent existence; thus producing an additional finger or thumb on each hand, a double pair of arms or legs, a double head or trunk, or even a complete double body. In the hypertrophy of a regular or normal part, the new tissues are still developed according to a regular morphological type; but they have not the power of individualizing themselves (so to speak), and are so incorporated with the normal elements as to augment the size of the existing organ. In the formation of a tumour, on the other hand, whilst its component tissues are themselves perfectly formed, and have a marked power of independent growth, the mass composed of them is altogether amorphous, its configuration being usually determined rather by the physical conditions under which it is produced, than by any peculiar tendencies of its own; so that we recognize the action of the formative power, undirected by that morphological *nisus*, which normally models (so to speak) the growing tissues into the likeness of the organ to which they belong. But further, in many of the large class of tumours distinguished as 'malignant' (§ 616), the development of tissue has not gone to the extent of producing any of those species of which the body is normally constituted; and in this respect, as well as in their tendency to rapid degeneration, the vital endowments of their elements must be reckoned as below those of the normal tissues.—It is not always easy to draw the line between certain tumours and supernumerary parts, especially when the production of the former is symmetrical; but the first appearance of the latter never takes place save during embryonic life, and their structure is more complex, and is more conformed to the plan and construction of the body at large, than is that of tumours, whose production may take place at any period of life. And between those tumours which are known as 'piliferous' and 'dentigerous cysts,' and those encysted embryoes (usually incomplete in their formation) which are sometimes found in the bodies even of males, it is impossible to establish any line of demarcation sufficiently precise to prevent our recognizing them as all having the same origin and being expressions of the same power,—the simple cyst being a kind of rude attempt at the production of a distinct

* See "Princ. of Phys., Gen. and Comp.," §§ 646, 709; Prof. Vrolik in "Cyclop. of Anat. and Phys.," art. 'Teratology,' vol. iv. p. 976; and Prof. Allen Thomson on 'Double Monstrosity,' in "Edinb. Monthly Journal," June and July, 1844.

individual,—and the encysted embryo being but the result of an unusually high development of a proliferous cyst.

598. The state of *Atrophy* is in all respects the very opposite of Hypertrophy; consisting in such a reduction in the rate of formative activity as compared with that of their 'waste,' that their nutrition is no longer maintained at its previous standard; so that they are gradually reduced in bulk, or degenerate into some inferior histological type, or (which is the more common occurrence) undergo both diminution and deterioration at the same time. It is important to bear in mind, that Atrophy may take place, either locally or generally, from an unusually rapid disintegration of the tissues, uncompensated by a corresponding increase in the rate of their nutrition; of the former we have a characteristic example in the rapid reduction of the bulk of the uterus after parturition, and of that of the mammary glands after the sudden cessation of lactation; of the latter we see an illustration in the rapid wasting of the system, which takes place in the irritable state that results from excessive and prolonged exertion of body or anxiety of mind, especially when accompanied with want of sleep, the increased disintegration being marked by the presence of an unusual amount of urea and of the alkaline phosphates in the urine. But in the ordinary forms of Atrophy, there is not merely a *relative* but an *absolute* reduction in the rate of the formative process, or a lowering of its standard of perfection; and here also we have to look for its causes, on the one hand, in the condition and supply of the blood, and, on the other, in the formative capacity of the tissues themselves.—The Atrophy dependent upon an insufficient supply of nutritive materials, may be either general or partial. General atrophy, or emaciation, is a necessary result of deficiency of food; but it may also proceed from an imperfect performance of the assimilating processes, whereby the nutritive materials do not receive their requisite elaboration, as in cases of disease of the mesenteric glands; or from an unusual energy of the metamorphic processes, whereby the azotized constituents of the food are decomposed into excrementitious products, without undergoing assimilation at all, as seems to be the case in diabetes. Of the atrophy of a particular tissue consequent upon the deficiency of its proper materials in the blood, we have an example in the reduction of the adipose, when there is no surplus of fatty matter to serve for its nutrition, but on the other hand a withdrawal of the contents of the fat-cells into the circulating current, whilst the nutrition of the muscular and other azotized tissues may proceed with its usual vigour.—Instances of complete local atrophy, or gangrene, resulting from deficiency in the supply of blood to a part, are by no means unfrequent; but it is less common to meet with a prolonged diminution in the rate of nutrition from such a cause, since a partial obstruction to the circulation is usually removed after a short time by the enlargement of the collateral vessels. Yet there are peculiar circumstances under which this does not take place; thus Mr. Curling has shown that atrophy may occur in fractured bones, in that portion which is cut off from the direct supply of blood through the great medullary artery; the circulation being restored by anastomosis to such an extent as to prevent the death of the bone, but not so completely as to support vigorous nutrition.*—The most frequent

* "Medico-Chirurgical Transactions," vol. xx.

cause of Atrophy lies, however, in the deficiency of formative power in the tissues themselves, arising from the decline of that capacity which they inherit from the germ. This decline, as already shown, takes place in the body at large, as a part of the regular order of things, with the advance of years, and also normally occurs in particular organs at earlier periods of life; but it sometimes takes place prematurely, either in the body at large, or in particular organs, so that they undergo a wasting or degeneration without any ostensible cause. A remarkable example of this has been already referred-to, in the account of Cartilage (§ 253); and many similar cases might be cited. There is reason to believe that 'fatty degeneration,' the form under which degeneration most commonly presents itself (§ 593), is in reality far more frequent than simple wasting of the tissues; but it attracts less notice, because their bulk is little or not at all diminished; and it is only when their function becomes impaired, that attention is seriously drawn to the change. This form of Atrophy can seldom be attributed to antecedent diminution in functional activity; for it is most common in organs upon which there is the most constant demand for the energetic performance of their respective duties, as, for instance, in the heart, the kidneys, and the liver. But the formative activity of Muscles and Nerves is so closely dependent, as already several times pointed out, upon the active exercise of their functional powers, that atrophy is certain to supervene if this be interrupted; and this atrophy may or may not present itself under the form of fatty degeneration; a shrinkage of the parts, concurrently with the production of an increased amount of fat in them, being perhaps the mode in which it most frequently takes place. Atrophy of one part, moreover, may be dependent upon atrophy or imperfect functional activity of another, if the two be so related in their normal functions, that a decline of one involves a corresponding decline in the other. Thus if a motor nerve be paralyzed, the muscles which it habitually calls into action will be atrophied; and this will equally happen, whether the want of motor power depend upon a deficient production of it in the nervous centres, or upon an interruption to its conduction through the trunks.* On the other hand, if the muscles of a part undergo degeneration from want of use (as in disease of the hip-joint), the nerves which supply them also suffer. The same is the case in regard to the nerves and organs of sense: for atrophy of the eye will occasion atrophy of the optic nerve,

* The Author has for some time had under his observation a case in which three males of a family have progressively become affected, between the ages of 3 and 5 years, with fatty degeneration of the muscles, which has proceeded in the most advanced case to the almost complete obliteration of their normal structure. This change had been considered by many eminent practitioners to be idiopathic, that is, to have its primary origin in the muscular tissue; and the measures which had been employed to arrest it had been of no avail whatever. It was a strong argument, however, against such a view of the case, that, in the *heart* of the eldest son, who died of fever at the age of 16, no fatty degeneration could be discovered; and on making inquiry into the history of the parents and their families, ample evidence was discovered for the belief, that the disease was dependent upon want of functional power in the nervous centres. Acting on this view, it was recommended that the muscular system should be kept as much as possible in a state of active exercise, and that a weak galvanic current should be frequently transmitted through the limbs from the spine. This treatment has proved so far successful, that the progress of the disease appears to have been arrested in the most-advanced case, whilst a decided improvement has taken place in the condition of a younger child, who was previously passing rapidly into a state resembling that of his elder brothers.

and destruction of the optic ganglia will induce atrophy of the eyes and optic nerves. Even the bones of a limb will suffer, in cases of atrophy of the muscles consequent upon disuse; for in the case already cited (§ 313) from Dr. J. Reid, the bones of the quiescent limb only weighed 81 grains, whilst those of the exercised limb weighed 89 grains.—It is an important fact, which was first pointed out by Mr. Paget,* that when fatty degeneration is commencing in any tissue which is characterized by the persistence of its nuclei, it is in the nuclei that the first alterations are seen; for they become pale and indistinct, and gradually disappear altogether, almost before any other change is discernible in the contents of the cells or tubes to which they appertain; but in atrophy from mere decrease, this disappearance of the nuclei does not occur.

599. *Reparative Process.*—The nutritive operations take place, with extraordinary energy and rapidity, in the process of *Reparation;* by which losses of substance, occasioned by injury or disease, are made good. In its most perfect form, this process is exactly analogous to that of the *first development* of the corresponding parts; and its results are as complete in the one case as in the other. In fact, among the lowest tribes of Animals, we find these two conditions blended, as it were, together; for the process of reparation may be carried in them to such an extent, as to regenerate the whole organism from a very small portion of it. In the Hydra, or Fresh-water Polype, there would seem to be scarcely any limit to this power; for, even if the body of the animal be minced into small fragments, every one of these can produce a new and perfect being. In this manner, no less than forty have been artificially generated from a single individual.—In ascending the Animal scale, we find this reparative power less conspicuous, because limited in its exercise to particular tissues and to comparatively insignificant parts of the body; and in Man, as in other warm-blooded Vertebrata, the regenerative power is for the most part restricted in its exercise, as Mr. Paget has pointed-out,† to three classes of parts;—namely, (1). "Those which are formed entirely by nutritive repetition, like the blood and epithelia, their germs being continually generated *de novo* in the ordinary condition of the body; (2). Those which are of lowest organization, and (what seems of more importance) of lowest chemical character, as the gelatinous tissues, the areolar and tendinous, and the bones; (3). Those which are inserted in other tissues, not as essential to their structure, but as accessories, as connecting or incorporating them with the other structures of vegetative or animal life, such as nerve-fibres or blood-vessels. With these exceptions, injuries or losses are capable of no more than repair in its limited sense; i.e. in the place of what is lost, some lowly-organized tissue is formed, which fills up the breach, and suffices for the maintenance of a less perfect life."—Yet, even thus restricted, the operations of this power are frequently most remarkable; and are in no instance, perhaps, more strikingly displayed, than in the re-formation and remodelling of an entire bone, when the original one has been destroyed by disease. That this power is intimately related to that by which the organism is normally built up and maintained, is evident, not merely from the peculiar mode

* 'Lectures on Nutrition,' &c., in "Medical Gazette," 1847, vol. xl. pp. 145, 146.
† 'Lectures on Reproduction and Repair,' in "Medical Gazette," 1849, vol. xliii. p. 1022.

in which it is exercised,—its tendency being always to reproduce each part in the form and structure characteristic of it at the particular period of life, and not according to its embryonic type,—but also from the fact that it is more effectual in the state of growth than in the adult condition, and that it can do far more in the embryonic state, when development as well as growth is taking place, than after the developmental process has ceased. In fact, as Mr. Paget has pointed out (loc. cit.), its amount at different periods of existence, as in different classes of animals, seems to bear an inverse ratio to the degree of development which has already taken place. Thus it is well known to every Practitioner, how much more readily and perfectly the lesions resulting from accident or disease are repaired in childhood and youth, than they are after the attainment of the adult state. And there is evidence that during embryonic life, the regeneration of lost parts may take place in a degree to which we have scarcely any parallel after birth; for Prof. Simpson has brought together numerous cases, in which, after 'spontaneous amputation' of the limbs of a fœtus, occurring at an early period of gestation, there has obviously been an imperfect attempt at the re-formation of the amputated part from the stump;* and it seems probable, from the history of normal development, that in the cases in which perfect hands and feet have been present without the corresponding limbs, these hands and feet have been secondary productions from the stumps of amputated limbs, since any original defect of development would have affected the hands and feet rather than the arms and legs. There are occasional instances however, in which this regenerative power has been prolonged to an unusually late period; thus an instance is recorded, on authority that can scarcely be doubted, of the twice-repeated re-production of a supernumerary thumb, after it had been twice completely removed;† and the Author has been assured by a very intelligent Surgeon, that he was cognizant of a case in which the whole of one ramus of the lower jaw had been lost by disease in a young girl, yet the jaw had been completely regenerated, and teeth were developed and occupied their normal situations in it.‡

600. It has been a general opinion among British surgeons (founded upon what they believe, but erroneously, to have been the doctrine of Hunter), that Inflammation is essential to the process of Reparation. There is no doubt that, as usually conducted, the healing of wounds is attended by a greater or less degree of Inflammation; but it does not hence follow that this morbid condition is essential to the renewal of the healthy state; and in fact it can be shown that, in the majority of cases, the occurrence of Inflammation is injurious rather than beneficial. It was by Dr. Macartney that the first clear enunciation of this important truth was made; and his conclusions, founded upon a philosophical

* These cases were brought by Prof. Simpson before the Physiological Section of the British Association at its Meeting in Edinburgh, Aug. 1850. The Author, having had the opportunity of examining two living examples, as well as Prof. Simpson's preparations, is perfectly satisfied as to the fact.

† See Mr. White's Treatise on the "Regeneration of Animal and Vegetable Substances," (1785) p. 16.

‡ For a sketch of the Regenerative Process as performed in different tribes of Animals, see "Princ. of Phys., Gen. and Comp.," §§ 645 and 646, and the account of each class in Chap. VII.

comparative survey of the operations of Reparation and Inflammation, as performed in the different classes of animals,—namely, "that the powers of reparation and reproduction are in proportion to the indisposition or incapacity for inflammation; — that inflammation is so far from being necessary to the reparation of parts, that, in proportion as it exists, the latter is impeded, retarded, or prevented;—that, when inflammation does not exist, the reparative power is equal to the original tendency to produce and maintain organic form and structure;—and that it then becomes a natural function, like the growth of the individual, or the reproduction of the species,"*—may be regarded as substantially correct, although requiring some modification in particular cases.

601. The simplest of all the methods of healing of an open wound, is that which is termed by Dr. Macartney 'immediate union.' It is often seen in the case of small incised wounds, such as cuts of the fingers, or the incision made in venesection, in which the two edges can be brought into close approximation, so that they grow together without any connecting medium of blood or lymph; but it sometimes occurs in larger ones,† and as it is the best imaginable process, the surgeon ought to favour it as much as possible, by procuring the most exact coaptation of the wounded parts, and by repressing any tendency to inflammation, which will interfere with it. This is the mode of union which was spoken of by John Hunter as 'healing by the first intention.' He supposed that the union takes place through the medium of the blood intervening between the lips of the wound, which undergoes organization into a connecting tissue; but it is now certain that although blood *may* become organized, especially when effused into a wound secluded from the air, yet that its intervention rather opposes than favours healing by immediate union.

602. That which is commonly known amongst British Surgeons as 'healing by the first intention,' is that which was designated by Hunter as 'union by adhesion' or by 'adhesive inflammation.' This process takes place in the case of incised wounds, of which the edges are not brought into perfect coaptation, or in which some inflammatory action is present, which gives rise to the effusion of plastic lymph. In either case, the connection is finally re-established by the organization of the lymph, into which vessels pass from both surfaces; but the intervention of this bond is manifested in the persistence of the cicatrix, which is quite distinguishable by its peculiar appearance from the surrounding tissue. A very good example of this process, as it takes place under favourable circumstances, is presented after operations for hare-lip; the wound left by which, however, may partly heal by 'immediate union.' Even the moderate effusion of lymph, to a degree that is altogether salutary, cannot be regarded as alone sufficing, under such circumstances, to constitute Inflammation. It is well known that if a slight wound, which is thus healing, be provoked to an increased degree of inflamma-

* Dr. Macartney's "Treatise on Inflammation," p. 7.

† Mr. Paget mentions a case of extirpation of a mammary tumour, in which the greater part of the wound was found to have healed after this fashion; the skin and fascia having so firmly adhered, that no indication existed of their previous detachment; and no effusion of coagulable lymph, or production of a connecting tissue, being detectible by microscopic examination.

tion, its progress is interrupted; and all the means which the Surgeon employs to promote union, are such as tend to prevent the accession of this state.—The only case in which the concurrence of Inflammation can be regarded as salutary, is that in which there is a deficiency of Fibrin in the blood, causing a deficient *organizability* of the lymph. It has been seen that the amount of fibrin is rapidly increased by inflammation: and the Surgeon well knows that a wound with pale flabby edges, in a depressed state of the system, will not heal, until some degree of Inflammation has commenced. But when the inflammatory state has developed itself, in however trifling a degree, there is always a risk of its proceeding further, and occasioning a degeneration of the plastic material, so that the formation of pus-cells and the effusion of purulent fluid take place, instead of the development of uniting tissue.

603. The reparation of wounds, in which there has been so great a loss of substance that neither immediate union nor adhesion by a thin layer of coagulable lymph can take place, is accomplished by the gradual development of new tissue from the 'nucleated blastema' with which the cavity is first filled. But this may take place in different modes, according to the degree in which it is disturbed by the Inflammatory process; and it should be the great object of the Surgeon to procure the most favourable method of its performance. It has been shown by Mr. Paget, that the mode in which the process of filling-up is accomplished, differs essentially according as the wound is subcutaneous, or is exposed to air. In the former case, the nucleated blastema is gradually developed into fibrous tissues (§ 224) without any loss, and usually with freedom from local inflammation (beyond what may have been requisite for the production of the plastic fluid), as well as from constitutional irritation. In the latter case, the nucleated blastema is developed into cells; and those on its exposed surface are unable, either from degeneration or from imperfect development, to pass on to any higher form of organization, but take on the characters of pus-cells, and are only fit to be cast off. Hence there is a continual loss of plastic material, the amount of which, in the case of an extensive suppurating sore, forms a most serious drain upon the system; whilst, at the same time, the local inflammation gives rise to more or less of constitutional disturbance, and the formation of new tissue is by no means so perfect as in the preceding case. In cold-blooded animals, however, the contact of air does not produce this disturbance; and we see wounds with extensive loss of substance gradually filled-up in them by the development of new tissue, without any suppuration or other waste of material, very much as in the subcutaneous wounds of warm-blooded animals. This method of healing, which has been termed by Dr. Macartney the 'modelling process,' is nothing else than healing by granulations under the most favourable circumstances; and to procure this should be the endeavour of the Surgeon, who too frequently considers suppurative granulation as the only means by which an open wound can be filled up. The difference between the two modes of reparation is often one of life and death, especially in the case of large burns on the trunk in children; for it frequently happens that the patient sinks under the great constitutional disturbance occasioned by a large suppurating surface, although he has survived the immediate shock of the injury.—Now the means adopted by Nature to bring this about, in warm-blooded animals, is the formation

of a scab; which reduces the wound more nearly to the condition of a subcutaneous one, so that the reparative growth and formation of new tissue takes place (under favourable circumstances) without any suppuration, and with scarcely any irritation; the subsequent cicatrix, too, being much more like the natural parts, than are any scars formed in wounds that remain exposed to the air. In the Human subject, however, the process is far less certain than it is among the lower animals, owing to the liability to inflammation in the wounded part, and the consequent effusion of fluid, which produces pain, compresses the wounded surface, or forces off the scab, with great discomfort to the patient, and retardation of the healing. Small wounds, however, in persons of good habit of body, and in parts which can be completely kept at rest, readily heal in this manner; and large wounds have been known to close, in the same desirable mode, beneath a clot of inspissated blood. In fact, among 'uncivilized' nations, whose habits of life are favourable to health,—their bodies being continually exposed to fresh air, their food wholesome and taken in moderation, and their drink water or other unstimulating liquids,—there seems to be as great a tendency to this method of reparation as among the lower animals; and the difficulty of procuring it among the members of 'civilized' communities is owing, without doubt, to the *unnatural* conditions under which they too frequently live. Seeing as we continually do, the effects of foul air, of habitual excess in diet, and of the constant abuse of stimulants, in impairing that form of the reparative process which must be regarded as the least favourable, namely, the closure of a wound by suppurating granulations, it is very easy to comprehend that, to induce the most favourable method, the most perfect freedom from all pernicious agencies should be required.

604. The most effectual means of promoting this kind of Reparative process, and of preventing the interference of Inflammation, vary according to the nature of the injury. The exclusion of air from the surface, and the regulation of the temperature, appear the two points of chief importance. By Dr. Macartney, the constant application of moisture is also insisted on.* He states that the immediate effects of injuries, especially of such as act severely upon the sentient extremities of the nerves, are best abated by the action of "*steam* at a high but comfortable temperature, the influence of which is gently stimulant, and at the same time extremely soothing. After the pain and sense of injury have passed away, the steam, at a lower temperature, may be continued; and, according to Dr. M., no local application can compete with this, when the Inflammation is of an active character. For subsequently restraining this, however, so as to promote the simple reparative process, Water-dressing will, he considers, answer sufficiently well; its principal object being the constant production of a moderate degree of Cold, which diminishes, whilst it does not extinguish, sensibility and vascular action, and allows the Reparative process to be carried-on as in the inferior tribes of animals. The reduction of the heat in an extreme degree, as by the application of ice or iced water, is not here called for, and would be positively injurious; since it not only renders the existence of Inflammation in the part impossible, but, being a direct sedative to all vital actions,

* "Treatise on Inflammation," p. 178.

suspends also the process of restoration. The efficacy of Water-dressing in injuries of the severest character, and in those which are most likely to be attended with violent Inflammation (especially wounds of the large joints) has now been established beyond all question; and its employment is continually becoming more general.*—Other plans have been proposed, however, which seem in particular cases to be equally effectual. To Dr. Greenhow, of Newcastle, for instance, it was accidentally suggested, a few years since,† to cover the surface of recent burns with a liquefied resinous ointment, so as to form an artificial scab; and he states that in this manner suppuration may be prevented, even where large sloughs are formed; the hollow being gradually filled up by new tissue, which is so like that which has been destroyed, that no change in the surface manifests itself, and none of that contraction, which ordinarily occurs even under the best management, subsequently takes place. A plan has, moreover, been proposed for preventing suppuration, and promoting reparation by the 'modelling' process, which consists in the application of *warm dry air* to the wounded surface. Although the experiments yet published have not been entirely satisfactory, they seem to show that, whilst the process of healing may be slower under treatment of this kind, it is attended with less constitutional disturbance than is often unavoidable in the ordinary method; and, that it may, therefore, be advantageously put in practice in those cases, in which the condition of the patient requires every precaution against such an additional burthen,—as after amputation in a strumous subject.‡

605. When the process of healing of an open wound by Suppurative Granulation is attentively watched, it is seen that the first stage is the formation of a "glazing" on the exposed surface, which closely resembles the buffy coat of the blood, being composed of coagulated fibrin and colourless corpuscles; in this manner a sort of imperfect epithelium may be formed within half an hour after the surface has been laid bare. The increase of this glazing is the prelude to the formation of granulations; but whilst it is going on, there is, in and about the wound, an appearance of complete inaction, a sort of calm, in which scarcely anything appears except a slight oozing of serous fluids from the wound, and which continues from one day to eight, ten, or more, according to the nature and extent of the wounded part, and the general condition of the body. "This calm," says Mr. Paget, "may be the brooding-time for either good or evil; whilst it lasts, the mode of union of the wound will, in many cases, be determined; the healing may be perfected, or a slow uncertain process of repair may be but just begun; and the mutual influence which the injury and the patient's constitution are to exercise on one another, appears to be manifested more often at or near the end of this period, than at any other time." The cessation of this period of calm, and the active commencement of the reparative operations, are marked by the restoration of the flow of blood in the vessels of the wounded part; but the current is not altogether normal, being slower but fuller than natural, so that on the whole more blood than usual passes through the capillary plexus. This

* See an account of the results of this treatment by Dr. Gilchrist, in "Brit. and For. Med. Rev.," July, 1846, p. 242.

† "Medical Gazette," Oct. 13, 1838.

‡ See M. Jules Guyot "De l'emploi de la Chaleur dans le Traitement des Ulcères, &c."

increased afflux of blood is followed by effusion of plastic material in increased proportion; and it is from this effusion, that the granulating process properly commences.—The plastic material effused upon the surface of an open wound is first developed into cells; and these cells, in the deeper portions of the effusion, are metamorphosed into fibrous tissue, of which the substance of the granulations is composed. Those which are formed upon the surface, however, are converted into pus-cells (§ 614); in some instances (as Mr. Paget has pointed out) by degeneration from a higher development; in other cases by an originally imperfect development: and thus the granulation-surface is constantly in a state of morbid action, and a large proportion of the plastic material is completely wasted. The layer of pus, however, serves as a sort of epithelium for the subjacent granulation-tissue, in which we find not only a complete formation of cells, but a commencement of the metamorphosis of these cells into fibres, before blood-vessels make their appearance in the tissue. These blood-vessels are formed by "out-growth" from the subjacent capillaries, in the mode formerly described (§ 295). From the investigations of Mr. Liston, it appears that the vessels of the subjacent tissue are much enlarged, and assume a varicose character. The bright red colour of the granulations, however, does not depend on their vascularity alone; for the cells themselves, especially those most recently evolved, are of nearly as deep a colour as the blood-corpuscles; and the sanguineous exudation which follows even the slightest touch of the granulating surface, does not proceed from blood effused from the newly-formed vessels only; for the red fluid shed in this manner contains, besides blood-discs, newly-developed red cells, ruddy cytoblasts, pale granules, and reddish serum. It is a common property of animal cytoblasts, that they present a reddish colour on their first formation, when in contact with oxygen; but this hue they lose again, whether they advance to perfect development and become integral parts of a living tissue, or die and degenerate.

606. The process of Suppurative Granulation, then, appears to differ from the process of granulation as it takes place in closed wounds, or in a warm moist atmosphere (the "modelling process" of Dr. Macartney), essentially in this—that a large part of the exudation-corpuscles deposited on the wounded surface degenerates into pus in the former case, whilst none are thus wasted in the latter:—but that the existence of inflammation occasions a more copious supply of fibrin in the former case, and increases its tendency to become organized; the filling-up of a wound with granulations being thus a much more rapid process, than that renewal of the completely-formed tissues, which may take place in the absence of inflammation. The imperfect character of the granulation-structure is shown, by the almost complete disappearance of it after the wound has closed over. The portion of it in immediate contact with the subjacent tissue, however, appears to undergo a higher organization; for it becomes the medium by which the cicatrix is made to adhere to the bottom of the wound. It is very liable to undergo changes which end in its disintegration; as is evident from the known tendency to re-opening, in wounds that have been closed in this manner.

607. When two opposite surfaces of granulations, well developed, but not yet covered with cuticle, are brought into apposition, they have a tendency to unite, like the two original surfaces of an incised wound.

This method of union, which was noticed by John Hunter, has been appropriately termed 'secondary adhesion' by Mr. Paget. The surgeon may frequently have recourse to it with great advantage, when primary adhesion is impossible, and when the filling-up of the wound with granulations would be a tedious process, and very exhausting to the patient. In applying it to practice, it is essential to success, first, that the granulations should be healthy, not inflamed or profusely secreting, nor degenerated as those in sinuses commonly are; and secondly, that the contact between them should be gentle but maintained: it seems desirable, also, that the granulation-surfaces should be as much as possible of equal development, and alike in character.*

### 3.—*Abnormal Forms of the Nutritive Process.*

608. Under the preceding head, we have considered the chief variations in the degree of activity that are witnessed in the ordinary or normal conditions of the Nutritive process,—those conditions, namely, in which the products are adapted, by their similarity of character, to replace those which have been removed by disintegration. But we have now to consider those forms of this process,—in which the products are *abnormal,*—being different from the tissues they ought to replace. We shall confine ourselves to a brief examination of a few of some of the most important of these states; and that which first claims our consideration, on account of the frequency of its occurrence and the importance of its results, is *Inflammation.*—Although Pathologists have been accustomed to look for the 'proximate cause' of the phenomena which essentially constitute the Inflammatory state, or, in other words, for the first departure from the normal course of vital action, in the enlarged or contracted dimensions of the blood-vessels of the inflamed part, or in the altered rate of movement of the blood through it, yet it may now be safely affirmed that these are only secondary alterations, depending upon an original and essential perversion of that normal reaction between the blood and the tissues, which constitutes the proper Nutritive process. This perversion manifests itself (1) in a diminution in the formative activity of the tissues, leading to their degeneration and death; (2) in a tendency to augmented production of the plastic components of the blood; and (3) in the effusion of these components, either in a state in which they may pass into a low form of organized tissue, or in such a degraded condition that they are altogether unorganizable, and are fit only to be cast out of the body. Each of these phenomena requires a separate examination, both as to its causes and its consequences.

609. Although it has been customary to speak of Inflammation as a state of 'increased action' in the part affected,—of which increased action the augmentation in the bulk and weight of an inflamed part, and in the quantity of blood which passes through it, together with its higher temperature and more acute sensibility, would seem to furnish sufficient evidence,—yet all these signs are found to be deceptive when they are more closely examined; and the conclusion is forced upon us, that the

* On the whole subject of the Reparative Processes, see the admirable Lectures of Mr. Paget, in the "Medical Gazette," 1849; from which many of the foregoing statements and doctrines are adopted.

vital power of the part is really *depressed* rather than exalted. For the increase in bulk and weight is not due to such an augmentation of its proper tissue as would truly constitute Hypertrophy; on the contrary, even in the slightest forms of Inflammation there is such a diminution in the rate of its nutrition as really constitutes Atrophy; and such augmentation of the solid mass as may take place, is produced by the passage of the effused fluid into an organized tissue of the lowest kind, and this in virtue rather of its own plasticity, than of the vital force which it derives from the tissues which it infiltrates. That there has been an atrophy rather than a hypertrophy of the proper fabric of the part, becomes evident enough when the inflammation has passed away, and this newly-formed tissue undergoes degeneration and absorption. The only tissues in which there is any appearance of increased formation during the inflammatory state, are those which correspond in their low type of organization with the new tissue thus generated; namely, the areolar and other simple fibrous tissues, and also the osseous, of which the organized basis is of the same kind. When the Inflammation is more severe, the tendency to degeneration in the proper tissues of the part becomes very obvious; for it is by their *interstitial* decay and removal, that the cavity of an *abscess* is formed; it is by their *superficial* death and absorption or solution, that *ulceration* takes place; and it is in the death of a whole mass at once, that *gangrene* consists.—That a diminution in the formative activity of the tissues is an essential characteristic of the Inflammatory state, further appears from the study of its ætiology; for whether the causes to which the inflammatory attack may be traced are *local* or *general*, acting primarily upon the tissues of the part, or first affecting the blood, their operation is essentially the same. For the *local* causes are all obviously such as tend either directly to depress the vital powers, or to elevate them at first, and then to depress them by exhaustion. Of the former kind are cold and mechanical injury; also many chemical agents, whose operation tends to bring back the living tissues to the condition of inorganic compounds. Under the latter category are to be ranked all those agencies which produce over-exertion of the functional power of the part, amongst which may be named heat, when not too excessive to produce a directly destructive effect. Now cold, heat, chemical agents, and mechanical injury, when operating in sufficient intensity, at once *kill* the part, by entirely destroying, instead of merely depressing, its vital powers; and it is on the borders of the dead part, where the cause has acted with less potency, that we find the inflammatory state subsequently presenting itself. On the other hand, there can be no doubt that many inflammations have their origin in morbid conditions of the blood, which, without any other cause whatever, may determine all the other phenomena. This is most obvious with regard to those of a 'specific' kind; but it is also probably true of the majority of the so-called spontaneous or constitutional, as distinguished from traumatic inflammations. We seem, indeed, to be able to trace a regular gradation between inflammatory attacks which are entirely traceable to the introduction of a poison into the blood, and those which result from causes purely local. Under the first head we may unquestionably rank such inflammatory diseases as are producible by inoculation, the eruptive fevers for example; and scarcely less thoroughly demonstrated are the cases of rheumatism and gout, and

many inflammations of the cutaneous textures, which, when occurring in the chronic form, tend to exhibit a regular symmetry (§ 201). In all such cases, the local affections are the external signs of the general affection of the blood, just as are the inflammations produced by the introduction of arsenic or of other irritant poisons into the circulation; and they may in fact be reasonably attributed to the impairment of the formative activity of the parts upon which these poisons fix themselves, in virtue of their 'elective affinity' (§ 207), just as the peculiar functional activity of the nervous centres is affected by narcotic poisons. And this view of the really local action of what are primarily regarded as general or constitutional causes of inflammation, is confirmed by the fact, that the localization of the perverted nutritive condition is often determined (as Dr. W. Budd and Mr. Paget have remarked) by a previous or concurrent weakening or depression of the vital activity of the part. Thus a part which has been the seat of former disease or injury, and which has never recovered its vigour of nutrition, is always more liable than another to be the seat of local manifestation of blood-disease; it is, in common language, the 'weak part.'* And it frequently needs the concurrent operation of a local depressing cause, to fix and develope the action of the constitutional cause, or blood-disorder; thus, a rheumatic or gouty diathesis may exist for some time (as when, to use a common expression, the disease is 'flying about' the patient), and yet the poison may not have sufficient potency to produce an attack of acute inflammation, until the vitality of some particular organ becomes depressed by cold, over-exertion, or some similar influence, which would not have itself engendered the diseased action, had it not been for the concurrence of the morbid condition of the blood.—Thus we seem justified in concluding, that, whether the causes of Inflammation act directly upon the tissues of a part, or whether they act upon it through the intermediation of the blood, their effect is to produce a depression in its vital powers, which manifests itself in *a deficient formative activity*, and in *an increased tendency to degeneration*; and that this is one of the primary and essential conditions of Inflammation.

610. This view is by no means inconsistent with other manifestations of inflammation which have been supposed to indicate 'increased action;' and, in fact, it is in such striking accordance with the phenomena presented by the movement of the blood, when these are interpreted by the principles already laid down, as to afford a powerful confirmation to both doctrines. The usual condition of the vessels of an inflamed part is one of dilatation; and this may be fairly attributed to the lowered vitality of their walls, whereby they yield too readily to the distending force of

* A patient under Dr. W. Budd's care had Small-pox soon after a fall on the nates; the pustules were thinly scattered every where, except in the seat of former injury, and on this they were crowded as thickly as possible. So a man who was under Mr. Paget's care with chronic inflammation of the synovial membrane of the knee-joint, and general swelling about it, having been attacked with Measles, the eruption over the diseased knee was a diffused bright scarlet rash. So Impetigo appears about blows and scratches in unhealthy children, and Erysipelas first attacks the seat of local injury in men with unhealthy blood. Perhaps as good an example as any is afforded by the uniform limitation of the inflammation consequent upon the introduction of Vaccine matter into the blood, to the spots in which the puncture was made; notwithstanding that the whole mass of blood is affected by it, as is shown by its incapacity for subsequently developing the poison of small-pox.

the current of blood. But this current moves too slowly; and its retardation may gradually increase, in the part most intensely inflamed, to the point of complete stagnation. Now this altered rate of movement cannot be attributed to any general cause: nor can it be accounted-for by the change in the diameter of the vessels; for, on the one hand, it may occur with a constricted state of the vessels, whilst, on the other, in the vessels surrounding the inflamed part, which partake of the dilated condition, the flow of blood is so far from being retarded, that it usually takes place more rapidly than usual. But it may be fairly considered as the result of the lowered or suspended nutritive activity of the part, which will tend to retard or entirely check the motion of blood in the systemic capillaries, just as the want of aeration retards or checks the pulmonary circulation (§ 527). It is quite true that a larger amount of blood passes through a limb, of which *some part* is in a state of active inflammation, than passes through the corresponding sound limb; but this is far from indicating 'increased action' in the inflamed part, being dependent upon the augmented flow of blood through the tissues which surround it; and if *the whole* of a limb be in a state of inflammation passing-on to gangrene (as occurs when a 'frost-bitten' limb has been incautiously warmed), the amount of blood which passes through it is diminished.—It would be just as erroneous to assume the elevated temperature of an inflamed part as a sign of 'increased action' in it; for this elevation is no doubt attributable in part to the augmented flow of blood through the surrounding vessels; and, so far as it depends upon local changes, it obviously indicates a more rapid disintegration of tissue, rather than a more energetic production of it; since it is in the former state rather than in the latter, that the conditions of the development of heat (on the chemical theory) are supplied, as we see that the heat of a muscle is the greatest when it is being disintegrated by active exercise (§ 330), not when it is being repaired by the formation of new tissue in the intervals of repose. But, as Mr. Paget justly remarks, "this phenomenon is involved in the same difficulty as are all those that concern the local variations of temperature in the body; difficulties which the doctrines of Liebig, however good for the general production of heat, are quite unable to explain." (See CHAP. XIII.)—And lastly, with regard to the unusual tenderness of inflamed parts, this is obviously due to such a combination of causes, none of which can be legitimately held to indicate an increase of its proper vital activity, that nothing can be rested on this alone; especially as we see an augmentation in the susceptibility of the sentient nerves, under many circumstances (as in hysterical disorders), in which, far from an *augmented* there is obviously a *diminished* activity in the parts from which they spring.—That neither an alteration in the circulation of a part, nor a departure from the normal condition of its nervous supply, can be regarded as one of the essential phenomena of inflammation, is obvious from this, that the most important phenomena of inflammation may present themselves, as results of injury or disease, in parts that have neither blood-vessels nor nerves: this is seen in the deposition of lymph in the cornea, in the ulceration of the cornea and of articular cartilages, and in other morbid actions in these parts, which, if ever they are vascular, become so only after the effusion of lymph in them, the new vessels being formed in this lymph, and not in the tissues themselves.

Here it is obvious that the whole change consists in a perversion of the nutritive actions which the tissues ought to carry-on, at the expense of the materials which they draw from the blood of the surrounding vessels (§§ 253, 254).

611. Of the alterations in the condition of the *Blood* in Inflammation, an account has already been given (§§ 171-177); and it is here only necessary to recapitulate them. The most characteristic is the augmentation either of the organizable or plastic fibrin, or of the organized colourless corpuscles; the increased production of these two components seeming to bear in some degree a relation of reciprocity, the one to the other. The increase of Fibrin may be considered as the alteration most characteristic of a previously healthy and vigorous state of the system; and it is in the inflammations which occur in such subjects, that the effusions are most strongly disposed to become organized, and show the least tendency to undergo degenerative changes. On the other hand the increase of the Corpuscular element seems to occur in cachectic or otherwise unhealthy individuals; and the inflammatory effusions, which partake of the same character, are far less plastic originally, and are extremely prone to undergo degeneration, either at the time of their effusion, or subsequently. With this increase in the proportion of fibrin and colourless corpuscles, separately or in combination, there is a diminution in the proportion of the red corpuscles, albumen, and salts of the blood. None of these changes, however, can be legitimately regarded as originally or essentially characteristic of the inflammatory condition; they are, in fact, to be looked-on rather as the results of its establishment, constituting that series of alterations in the circulating fluid, which is of parallel order to that which occurs in the solid tissues wherein the inflammatory action has been set up.

612. The Inflammatory state is further characterized by the *effusion* of certain of the components of the Blood, upon the surface, or into the substance, of the inflamed tissues.—The effusion of pure *serum* cannot be regarded as characteristic of inflammation; since it may take place as a mere result of congestion, especially when this congestion is due to an obstruction to the return of the blood; whilst, again, it may be due to an altered condition of the albuminous constituent of the blood, which favours its transudation (§ 167). The so-called serous effusions which are poured forth in inflammation, do in reality contain fibrin in solution; but this fibrin may not manifest its presence by spontaneous coagulation, until its passage into the solid state is favoured by some extraneous influence (§ 26). The presence of fibrin in such an effusion, however, is not in itself a sufficient proof of the existence of inflammation; for it has been shown by the experiments of Mr. Robinson,* that when the obstruction to the return of blood by the veins is so great as to occasion an excessive pressure within the capillaries, the fluid which transudes may contain enough fibrin to render it spontaneously coagulable.—The form of exudation which is most characteristic of Inflammation, is that which is known as *coagulable lymph;* it is much to be desired, however, that some other designation should be applied to it, since the term 'lymph' can only be appropriately employed for the fluid contents of the

* "Medico-Chirurgical Transactions," vol. xxvi. p. 51.

lymphatic vessels. The peculiar characteristic of this inflammatory exudation, is its capability of spontaneously passing into the condition of an organized tissue, either fibrous or cellular, or a mixture of both; and of thus forming 'false membranes' on inflamed surfaces, or solidifying the inflamed part by the interstitial production of similar lowly-organized textures. Although it has been too much the habit of Pathologists to speak of 'coagulable' or 'plastic lymph' as if it were always one and the same thing, yet it really presents various gradations of character, which are manifested in its different degrees of organizability, and in the diverse nature of the tissues developed from it; and, as Mr. Paget has pointed out,* there are two typical forms, the *fibrinous*, and the *corpuscular*, between which the others are intermediate. The former coagulates into a fibrous clot, resembling that of healthy blood, but usually showing a more distinct fibrillation. The latter (the 'croupous' exudation of Rokitansky) is characterized by the want of any proper coagulation, the fibrous clot being replaced by an aggregation of cells, which in their first appearance resemble very nearly the primordial condition of the corpuscles of the fluids of the absorbent vessels, and the colourless corpuscles of the blood. It is seldom, however, that either of these typical forms of lymph presents itself in a state of complete isolation from the other; they are much more commonly blended in various proportions, so that one or the other predominates; and it is mainly upon the preponderance of fibrin, that the 'plasticity' of the exudation (or its capacity for organization) depends; whilst according to the preponderance of corpuscles will be its tendency to degeneration. Thus the exudation of fibrinous lymph is the symbol of the 'adhesive' inflammation; whilst that of the 'corpuscular' is similarly characteristic of the 'suppurative' inflammation. It is obviously of great consequence to ascertain the conditions which determine the production of one or other of these states; and these, as Mr. Paget has pointed-out (loc. cit.), may be considered under three heads,—(1) the previous state of the blood, (2) the seat of the inflammation, and (3) the degree and character of the inflammation.

613. The *condition of the blood*, as determining that of the lymph, has been carefully studied by Rokitansky; who has shown that the characters of inflammatory deposits in different diatheses correspond very generally and closely with those of the coagula found in the heart and pulmonary vessels after death. The results of Mr. Paget's experiments on the same subject have been already cited (§ 196). And clinical observation fully confirms this doctrine by evidence of another kind; that, namely, which is afforded by the different course of the same specific diseases, in different individuals, according to the previously healthy or abnormal condition of their blood. There can be no doubt that a very large proportion of what are called 'unhealthy inflammations,' especially those of the erysipelatous type, are to be regarded as owing their peculiarity to a deficiency in the due elaboration of the fibrin, and to the low vitality of the cellular components of the blood, both of which conditions seem to be favoured by the presence of those decomposing matters, whose accumulation in the blood acts in many ways so prejudicially on the system at large (§ 210).—That the quality of the exudation is in some degree

* 'Lectures on Inflammation,' in "Medical Gazette," 1850, vol. xlv. p. 1012.

determined by the *seat* or *tissue* in which the Inflammation occurs, appears from the different character of the product of the disordered action occurring simultaneously in different organs of the same individual, and apparently under the operation of the same cause; thus it may happen that in pleuro-pneumonia, the two surfaces of the pleura become connected by an organized exudation of a fibrous character; whilst the effusion in the substance of the lung is rather of the corpuscular nature, and speedily passes into suppurative degeneration. Mr. Paget ingeniously proposes to account for the determining influence in question, on the idea that the inflammatory product is influenced at the time of its formation by the assimilative force of each part, so that it is to be regarded as a mixture of true lymph with its special product of assimilation; thus we observe that in inflammations of bone the lymph usually ossifies, in those of ligaments it is converted into a tough ligamentous tissue, and in those of secreting organs it contains a mixture of the ordinary secreted product.—The mode in which the *intensity* of the Inflammation affects the character of the effused lymph, is twofold. For, in the first place, the nature of the original effusion is likely to vary according to the degree in which the ordinary nutritive process is interrupted; since, the more intense the inflammation, the less will be the assimilating force of the part, and the more will the matters effused from the vessels deviate from the natural plasma which would be drawn from them in healthy nutrition; whilst on the other hand, when the inflammation is less severe, its product will not differ so widely from the natural one, and will from the first tend to manifest in its development some characters corresponding to those of the natural formations of the part. But, secondly, the influence of the inflammation, or rather of the depressed vitality of the inflamed tissues, is shown in the tendency to degeneration which it impresses on the exuded product; so that, even though this may be disposed to pass-on under favourable circumstances to the complete formation of an organized tissue, its development is early checked, and it undergoes retrograde metamorphosis, or else from the very commencement its development takes place according to a lower or degraded type. The normal product of the organization of either fibrinous or corpuscular lymph, is undoubtedly a tissue closely allied to the ordinary areolar or connective; it is of this that false membranes and adhesions are formed, and that the material of most thickenings and indurations of parts is composed; and it is by the production of this tissue also, that losses of substance are in the first instance repaired, and that divided surfaces are made to adhere. The mode in which this development takes place has been already described (§§ 223, 224). Various kinds of degeneration may take place, according to the stage at which the developmental process is checked; and among these, in tissues which have once attained an advanced stage of development, the most common is the fatty (§ 593).

614. But the most frequent of all the degenerations of lymph, being almost invariable when the lymph is placed *from the first* in conditions unfavourable to its development, is into the entirely unorganizable or *aplastic* product which is known as Pus. This, as already mentioned, is specially liable to occur in lymph which is originally rather corpuscular than fibrinous; and every gradation may be seen from the most characteristic form of the lymph-cell to that of the pus-cell. But it would

seem as if even the most perfectly fibrinous lymph may pass almost immediately into the condition of pus, when it is effused among tissues which are passing rapidly into a state of decomposition; and thus it appears to be, that in a phlegmonous inflammation, the lymph effused into the parts where the inflammatory process has been most intense (the stagnation of the blood being the most complete, and the normal tissues most disposed to disintegration), does not present the slightest tendency to a higher type of organization, but is developed from the first in the condition of pus, which fills the vacant space previously occupied by living tissue; whilst, in the surrounding parts, the fibrinous effusion produces a consolidation of the tissue, and thus forms the walls of the abscess, by which the purulent effusion is limited. Whether the disintegrating tissues are entirely removed by absorption (having previously undergone that degenerative softening which is requisite for the occurrence of this process), or whether they are broken-up and dissolved in the purulent fluid, is a point not yet determined.—The *conservative* nature of the fibrinous exudation, and the consequent importance of fibrin as an element of it, are well shown by the results of its deficiency. Thus if there be no 'sac' formed around a collection of pus, this fluid infiltrates through the tissues, and by its mere presence so impairs their nutrition, that a corresponding degradation takes place in the characters of the plastic material furnished for their assimilation; and thus the purulent effusion spreads without limit, and the tissues through which it percolates undergo rapid degeneration. So, again, when gangrene is spreading by contiguity (the proximity of the dead tissue tending to lower the vitality, and even to occasion the death, of that with which it is continuous), it is only when an inflammatory 'reaction' takes place, or, in other words, when an exudation of fibrinous lymph is poured into the substance of the tissues bordering on those which have lost their vitality, that a line of demarcation between the dead and the living parts is formed. And generally it may be said, that, as the ultimate tendency of Inflammation is to produce the disintegration of the part, the ultimate tendency of the fibrinous exudation is to keep its elements together, and to repair the losses which have taken place, although with a very inferior material.—It is only, however, with the subsidence of the inflammation, and the return to the ordinary type of nutrition, that the highest development of the lymph can take place; and it is in proportion as this occurs more speedily, that the recovery of the organization proper to the part is more completely effected.*

615. In persons of that peculiar constitution, which is termed *Scrofulous* or *Strumous,* we find an imperfectly-organizable or 'caco-plastic' deposit, or even an altogether *aplastic* product, known by the designation of *tubercular* matter, frequently taking the place of the normal elements of tissue; both in the ordinary process of Nutrition, and still more when Inflammation is set up. From an examination of the Blood of tuberculous

* The Author has pleasure in referring to Mr. Paget's 'Lectures on Inflammation' (Medical Gazette, 1850) as containing, in his opinion, the best exposition of the subject yet made public; and in acknowledging his obligations to them for much assistance in the short view of it given above. The fundamental doctrines on which the Author would now lay the greatest stress, however, are the same in all essential particulars with those which he has taught in previous Editions of this Treatise.

subjects it appears, that although the bulk of the coagulum obtained by stirring or beating it is usually greater than that of healthy blood, yet this coagulum does not consist of well-elaborated fibrine; for it is soft and loose, and contains an unusually large number of Colourless corpuscles, whilst the Red corpuscles bear an unusually small proportion to it. We can understand, therefore, that such a constant deficiency in plasticity must affect the ordinary nutritive process; and that there will be a liability to the deposit of cacoplastic products, without inflammation, instead of the normal elements of tissue. Such appears to be the history of the formation of Tubercles in the lungs and other organs, when it occurs as a kind of metamorphosis of the ordinary Nutritive process; and in this manner it may proceed insidiously for a long period, so that a large part of the tissue of the lungs shall be replaced by tubercular deposit, without any other ostensible sign than an increasing difficulty of respiration. In the different forms of tubercular deposit, we see the gradation most strikingly displayed, between the plastic and the aplastic formations. In the semi-transparent, miliary, grey, and tough yellow forms of Tubercle, we find traces of organization in the form of cells and fibres, more or less obvious; these being sometimes almost as perfectly formed as those of plastic lymph, at least on the superficial part of the deposit, which is in immediate relation with the living structures around; and sometimes so degenerated, as scarcely to be distinguishable. In no instances do such deposits ever undergo further organization; and therefore they must be regarded as *caco-plastic*. But in the opaque, crude, or yellow Tubercle, we do not find even these traces of definite structure; for the matter of which it consists is altogether granular, more resembling that which we find in an albuminous coagulum. The larger the proportion of this kind of matter in a tubercular deposit, the more is it prone to soften, whilst the semi-organized tubercle has more tendency to contraction. This is entirely *aplastic*.—It may be questioned, however, whether Tubercular matter is not always, even in its most amorphous state, a product of cell-formation; and whether the difference between the amount of organization which its several forms present, is not due rather to a variation in the degree of its subsequent degeneration, than to an original diversity in histological condition. On this view, Tubercle is to be considered as a formation *sui generis*, whose production is dependent upon a special taint in the blood; and just as the normal lymph-products vary greatly in their degree of vitality, so that some undergo a progressive and others a retrograde metamorphosis, so may tubercular deposits either retain their original characters more or less completely (though never advancing towards a higher character), or may undergo a very early and complete degeneration.* Now although Tubercular matter may be slowly and insidiously deposited, by a kind of degradation of the ordinary Nutritive process, yet it cannot be doubted that Inflammation has a great tendency to favour it; so that a larger quantity may be produced in the lungs, after a Pneumonia has existed for a day or two, than it would have required years to generate in the previous mode. But the character of the deposit still remains the same; and its relation to the plastic element of the blood is shown by the interesting fact, of no unfrequent occurrence,—that, in a

* See Mr. Paget in the "Pathological Catalogue of the Hunterian Museum," vol. i., p. 134; also Dr. Madden's "Thoughts on Pulmonary Consumption."

Pneumonia affecting a tuberculous subject, plastic lymph is often thrown out in one part, whilst tubercular matter is deposited in another. Now Inflammation, producing a rapid deposition of tubercular matter, is peculiarly liable to arise in organs, which have been previously affected with chronic tubercular deposits, by an impairment of the process of textural Nutrition; for these deposits, acting like foreign bodies, may of themselves become sources of irritation; and the perversion of the structure and functions of the part renders it peculiarly susceptible of the influence of external morbific causes.

616. We frequently meet with abnormal growths of a Fatty, Cartilaginous, Fibrous, or even Bony structure; which result from the development of these tissues in unusual situations, and appear to originate in some perverted action of the parts themselves (§ 597).—But there is another remarkable form of disordered Nutrition, which is concerned in producing what have been termed *heterologous* growths; that is, masses of tissue that differ in character from any which is normally present in the body. Most of these are included under the general designation of *Cancerous* or *Fungous* structures; and it has been shown by Müller and succeeding inquirers, that the new growth consists of a mass of cells; which, like the Vegetable Fungi, develope themselves with great rapidity; and which destroy the surrounding tissues by their pressure, as well as by abstracting from the Blood the nourishment which was destined for them. These parasitic masses have a completely independent power of growth and reproduction; and they can be propagated by inoculation, which may convey into the tissues of the animal operated-on, the germs of the peculiar cells that constitute the morbid growth, these soon developing themselves into a new mass. So it may be by the diffusion of the germs produced in one part, through the whole fabric, by means of the circulating current, that the tendency to re-appearance (which is one great feature in the *malignant* character of these diseases) is occasioned. But it would seem more probable that this character rather depends upon the presence of a morbid matter in the blood, of which the formation of the cancerous tissue is only the manifestation (§ 120); the local disease thus being the consequence of a constitutional cachexia, rather than the constitutional affection the result of the local disease.*

## CHAPTER XII.

### OF SECRETION AND EXCRETION.

#### 1. *Of Secretion in General.*

617. The literal meaning of the term Secretion is *separation;* and this is nearly its true acceptation in Physiology. But the ordinary processes of Nutrition involve a separation of certain of the components of the Blood, which are withdrawn from it by the appropriating power of the solid textures; and every such removal may be considered in the light of an act of *excretion,* so far as the blood and the rest of the organism are

* See Dr. Walshe on "The Nature and Treatment of Cancer;" and Mr. Simon's "General Pathology," Lect. VIII.

concerned (§ 202). Moreover, the separation of certain matters from the blood in a fluid state, either for the purpose of being cast forth from the body, or of being employed for some special purpose within it, which constitutes what is ordinarily known as Secretion, is effected by an agency of the same nature with that whose operation constitutes the essential part of the nutritive process; namely, the production and growth of cells. Hence there is no other fundamental difference between the two processes, than such as arises out of the diverse *destinations* of the separated matters, and the anatomical arrangements which respectively minister to these. For the products of the secreting action are all poured forth either upon the external surface of the body, or upon the lining of some of the cavities which communicate with it; and the cells by which they are separated from the blood, usually stand in the relation of epithelium-cells to those prolongations of the skin or mucous membranes, that form the follicles or extended tubuli, of which the Glandular organs are for the most part composed (§ 235), and are thus readily thrown-off from their free surfaces. Thus the act of Secretion essentially consists in the successive production and exuviation of the cells which minister to it; these cells giving up, by rupture or deliquescence, the substances which they have eliminated from the blood. Each group of cells is adapted to separate a product of some particular kind, which constitutes its special *pabulum;* and the rate of its production seems to depend *cæteris paribus* upon the amount of that pabulum supplied by the circulating fluid (§ 120). The substances at the expense of which the secreting cells grow, however, may not be precisely those which are subsequently cast forth at their death; for it is very probable that some of them, at least, undergo a certain degree of chemical transformation by the agency of these cells; the characteristic materials of the several secretions not always pre-existing *as such* in the blood.

618. A distinction may be drawn as regards this point, between those *Excretions*, the retention of whose materials in the Blood would be positively injurious, and those *Secretions*, which are destined for particular purposes within the system, and the cessation of which has no immediate influence on any other function than those for which they are respectively destined. The solid matter dissolved in the fluids of the latter class, is little else than a portion of the nutritive constituents of the blood; either so little altered as still to retain its nutritive character, as is the case with the casein of Milk, and with the albuminous constituent of the Serous fluid of areolar tissue and of serous and synovial membranes; or in a state of incipient retrograde metamorphosis, as seems to be the case with the peculiar 'ferments' of the salivary, gastric, pancreatic, and intestinal secretions. On the other hand, the characteristic ingredients of the Excretions are very different in character from the normal elements of the blood. They are all of them completely unorganizable; and they possess, for the most part, a simple atomic constitution. Some of them also, have a tendency to assume a crystalline form; which is considered by Dr. Prout to indicate their unfitness to enter into the composition of organized tissues. With regard to some of the chief of these, there is sufficient evidence of their existence, in small quantity, in the circulating Blood; but it is also clear, that they exist there as products of decomposition, and that they are destined to be separated from it as speedily as

possible. If their separation be prevented, they accumulate, and communicate to the circulating fluid a positively deleterious character. Of this, we have already seen a striking example in the case of Asphyxia (§ 574); and the history of the other two principal excretions, the Bile and Urine, will furnish evidence to the same effect.—As a general fact, then, it may be stated, that the materials of the Secretions pre-exist in the Blood, in a state nearly resembling that in which they are thrown off by the secreting organs: but that the materials of those secretions which are destined to perform some particular function within the economy, are derived from the substances which are appropriated to its general purposes; whilst those of the excretions are the result of the destructive changes that have taken place in the system, and cannot be retained in it without injury.

619. The composition and uses of the principal Secretions which are elaborated for special purposes within the economy, have already been partly described in connection with the functions to which they respectively minister; and the remainder will hereafter come under notice in the same manner. It is here intended, however, to consider that important system of Excretory operations, which serves to maintain the purity of the circulating fluid; by removing from it those products of the disintegration of the tissues, which are not capable of serving any purpose in the nutrition of the system, and which even act upon it as poisons; and also by withdrawing the products (apparently of a similar character) of the decomposition of those surplus alimentary materials, which, not being required for the nutrition of the tissues, undergo retrograde metamorphosis without having ever undergone the process of organization. The process of Respiration, as already pointed out (§ 535), is in part to be regarded as one of an excretory character, though the peculiar manner in which it ministers to the removal of carbon and hydrogen from the system, and its subserviency to other purposes, necessitate its separate consideration. The true Secreting processes which are to be regarded as more or less completely *excretory*, are the separation of bile by the Liver, that of urine by the Kidneys, that of perspiration by the Skin, and that of fæcal matter by the glandulæ of the Intestinal surface. The sum total of these, with the addition of the carbonic acid and watery vapour poured from the Lungs, and of the indigestible matter rejected in the form of fæces, must be equal to the total amount of the solid and fluid ingesta, and of the oxygen which disappears from the inspired air; the weight of the body remaining the same. The experiments of Dr. Dalton on his own person gave the following as the proportional quantities discharged through the principal channels of excretion.* The mean quantity of solid and liquid Aliment taken into the system daily (during 14 days in spring) being 91oz., or about $5\frac{3}{4}$lbs., the average amount of Fæces (including part of the solid matter of the bile) was 5oz.; the average amount of Urine was $48\frac{1}{2}$oz. daily; and, as the total weight of the body remained the same, the quantity of fluid and solid matter excreted by the Skin and the Lungs must have been $37\frac{1}{2}$oz. At other periods of the year, a variation was observed; especially in the relative amount of fluid passing off by the Urine, and by Cutaneous exhalation.—A more elaborate series of researches, however, has been recently made by M. Barral; a part of whose results has been given in

* "Edinburgh New Philosophical Journal," 1832, 1833.

he preceding chapter. The following are the average daily amounts of he several components of the food consumed, and of the various ex-cretions, in the five cases already referred-to (§ 566); water being ex-cluded in each case:—

| | *Ingested as Food.* | *Excreted* | | |
|---|---|---|---|---|
| | | *In Urine.* | *In Fæces.* | *By Lungs and Skin.* |
| Carbon . | 21770·4 grs. | 1060·7 grs. | 798·3 grs. | 19911·4 grs. |
| Nitrogen . | 1649·0 „ | 756·6 „ | 142·0 „ | 750·4 „ |
| Hydrogen | 3370·6 „ | 213·1 „ | 122·0 „ | 3035·5 „ |
| Oxygen . | 16446·7 „ | 563·6 „ | 467·8 „ | 15415·3 „ |
| Total . | 43236·7 „ | 2594·0 „ | 1530·1 „ | 39112·6 „ |

The water ingested amounted on an average to about three times the olid matters; that egested in various ways was commonly between one-fifth and one-sixth more, showing that there is an absolute production of vater in the system (§ 569). The following table gives the general esults of the comparison of the matters assimilated and excreted, so alculated that the sum in each case amounts to 100:—

| | Assimilated | | Excreted | | | |
|---|---|---|---|---|---|---|
| | *Food.* | *Oxygen.* | *As water; by exhalation.* | *As carbonic acid.* | *In the evacuations.* | *In other ways.* |
| A. | 72·2 | 27·8 | 33·8 | 32·3 | 33·2 | 0·7 |
| B. | 75·4 | 24·6 | 36·1 | 28·8 | 34·7 | 0·4 |
| C. | 76·7 | 23·3 | 38·2 | 28·3 | 33·2 | 0·3 |
| D. | 75·3 | 24·7 | 14·5 | 30·2 | 54·6 | 0·7 |
| E. | 72·5 | 27·5 | 31·0 | 31·5 | 36·9 | 0·8 |

620. It is obvious that the demand for the performance of the Excre-ory processes generally will, in the first place, arise, as in the case of Respiration, from the continual disintegration and decay to which the rganized fabric is liable in the maintenance of a merely *vegetative* exist-ence; and this will be constant during the whole life of Man, as of any ther warm-blooded animal, its amount varying with the degree of eneral vital activity.—But, secondly, the exercise of the *animal* func-ons, involving (as this does) the disintegration of the nervous and mus-ular tissues as the very condition of the evolution of their respective rces, becomes a special source of the production of excrementitious atter, the amount of which will vary with that of the forces thus de-eloped.—The removal of excrementitious matter may become necessary, hirdly, from the decomposition of superfluous aliment, which has never een assimilated. This would not be the case, if the amount of food pre-ared by the digestive process, and taken-up by absorption into the cur-ent of the circulation, were always strictly proportional to the demand r nutriment created by the wants of the system; but such a limitation ldom exists practically, in those individuals at least who do not feel them-lves obliged to put a restraint upon the indulgence of their ordinary ppetite; and all that is not appropriated to the reparation of the waste, to the increase of the bulk of the body, must be thrown-off by the xcretory organs. It has been already shown that an abundance of nu-itive material in the blood does not augment the production of the dinary tissues to any considerable extent (§ 596); and it would appear

that all such materials as are not speedily assimilated, pass rapidly into a state of retrograde metamorphosis. How large a proportion of the solid matters of the urine ordinarily has this source, will appear from facts hereafter to be stated (§ 640).—Moreover, in the last place, it cannot be deemed improbable that the changes which the crude aliment undergoes, from the time of its first reception into the absorbents and blood-vessels, to that of its conversion into organized tissues and special secretions, involve the liberation of many products of which the elements are superfluous, and therefore injurious to the system if retained in it. Thus it has been shown to be quite possible, that, in the production of Glutin (gelatin) from Albumen, an equivalent of Choleic (tauro-cholic) acid may be generated (§ 91, VI.). The condition of Organic Chemistry, however, is not yet such as to allow of anything being advanced with certainty under this head.—From these various sources, then, a large amount of effete matter is being continually received back from the tissues into the current of the circulation, or is generated in the blood by the changes to which it is itself subject; and it is the great object of the Excretory apparatus, to free that fluid from the products which would rapidly accumulate in it, but for the provision which is thus made for their removal.

621. Notwithstanding that, under ordinary circumstances, the several parts of the Excretory apparatus are limited, each to its own special function, yet we see that there are certain *complementary* relations between them, which make the action of one to a certain extent vicarious with that of another. Such a relation exists, for instance, between the lungs on one side, and the liver and intestinal glandulæ on the other; for, the more active the respiration, the less bile is secreted; whilst, if the respiration be lowered in amount by inactivity of body and a high external temperature, a larger proportion of unoxidized or imperfectly-oxidized excrementitious matters accumulate in the blood, giving rise to that augmented production both of the biliary and of the fæcal excretions, which constitutes diarrhœa.* And thus, on the other hand, when the liver is not adequately affecting the depuration of the blood from the constituents of bile, an augmentation of the respiration by active exercise in a low temperature gives most effectual relief.—Still more obviously vicarious, however, are the kidneys and the skin; for here we find that not only do the kidneys allow the transudation of whatever superfluous water may remain in the circulating current, after a sufficient amount has been exhaled from the skin to keep down the temperature of the body to its normal standard, but the skin actually assists in the elimination of one of those products of the metamorphosis of the azotized tissues, the removal of which has been until recently considered as the special function of the kidney. Consequently, whenever the due action of the skin as an excreting organ is interfered-with, it is the kidney especially that will be called-on to take its place; whilst, on the other hand, if it be thought necessary to relieve the kidney, this may be most effectually done by stimulating the skin to increased excretory activity.

622. This vicariousness of function among the Excretory organs pre-

* Such is probably the occasion of the 'bilious attacks' and 'autumnal cholera' so prevalent at the close of the summer; the subjects of these being most commonly persons who have not reduced their consumption of food during the warm season, in accordance with the diminished demand for the production of heat within the body.

sents itself far more remarkably, however, in certain states of disease; in which a complete 'metastasis of secretion' exhibits itself. The capability of one organ thus to take upon itself the special actions of another, seems to have reference to the community of function which exists in the secreting surface among the lower animals, in which there is none of that 'specialization' or setting-apart for particular offices, which we see in the higher; for it seems to be a general law in Physiology, that, even where the different functions are most highly specialized, the general structure retains, more or less, the primitive community of action which characterized it in the lowest grade of development.* It is in regard to the *Urinary* excretion, that the evidence on this point is most complete; for it seems to be established by a great mass of observations, that urine, or a fluid presenting its essential characters, may pass off by the mucous membrane of the intestinal canal, by the salivary, lachrymal, and mammary glands, by the testes, by the ears, nose, and navel, by parts of the ordinary cutaneous surface, and even by serous membranes, such as the arachnoid lining the ventricles of the brain, the pleura, and the peritoneum. A considerable number of such cases was collected by Haller:† many more were brought together by Nysten;‡ more recently Burdach has furnished a full summary of the most important phenomena of the kind;§ and Dr. Laycock has compiled a valuable collection of cases of urinary metastasis occurring as complications of hysteria.|| The following table of cases referred-to by the last of these authors, will give some idea of the relative frequency of the different forms of this curious affection :—

| Vomit. | Stool. | Ears. | Eyes. | Saliva. | Nose. | Mammæ. | Navel. | Skin. | Total. |
|---|---|---|---|---|---|---|---|---|---|
| 33 | 20 | 4 | 4 | 5 | 3 | 4 | 34 | 17 | 124 |

It is to be borne in mind, however, that cases of hysterical ischuria are frequently complicated with that strange moral perversion, which leads to the most persevering and ingenious attempts at deceit; and there can be little doubt that a good many of the instances on record, especially of urinous vomiting, are by no means veritable examples of metastasis. The proofs of the fact we are seeking to establish are, therefore, much more satisfactory when drawn from experiments upon animals, or from pathological observations, about which, from their very nature, there can be no mistake. Thus Mayer ¶ found that when the two kidneys were extirpated in the guinea-pig, the cavities of the peritoneum and the pleura, the ventricles of the brain, the stomach, and the intestinal canal, contained a brownish liquid having the odour of urine; that the tears exhaled the same odour; that the gall-bladder contained a brownish liquid not resembling bile; and that the testicles, the epididymis, the vasa deferentia, and the vesiculæ seminales, were gorged with a liquid perfectly similar to

* See "Princ. of Phys., Gen. and Comp.," §§ 351, 605.
† "Elementa Physiologiæ," tom. ii. p. 370.
‡ "Recherches de Physiologie et de Chimie pathologique," p. 265.
§ "Traité de Physiologie" (Jourdan's Translation), vol. viii. p. 248, *et seq.*
|| "Edinb. Med. and Surg. Journ.," 1838.
¶ "Zeitschrift für Physiologie," tom. ii. p. 270.

urine. Chirac and Helvetius are quoted by Haller as having tied the renal arteries in dogs, and having then remarked that a urinous fluid was passed off from the stomach by vomiting. A remarkable case is quoted by Nysten from Zeviani, in which a young woman having received an incised wound on the external genitals, which would not heal, the urine gradually became more scanty, and at last none could be passed even with the assistance of the catheter; at last dropsy supervened, with sweats of a urinous odour, and vomiting of a urinous fluid, which continued daily for thirty-three years. On post-mortem examination, the kidneys were found disorganized, the right ureter entirely obliterated and the left nearly so, and the bladder contracted to the size of a pigeon's egg. In some other instances, the urine appears to have been secreted, and then re-absorbed in consequence of some obstruction to its exit through the urinary passages. Thus Nysten quotes from Wrisberg a case in which, the urethra having been partially obstructed for ten years by an enlarged prostate, the bladder was so distended as to contain ten pounds of urine; and the serosity of the pericardium and of the ventricles of the brain exhaled a urinous odour. He cites other instances in which the presence of calculi in the bladder prevented the due discharge of the secretion; and in which a urinous liquid was ejected from the stomach by vomiting, or was discharged by stool. A still more remarkable case is recorded, of a girl born without either anus or external genitals, who nevertheless remained in good health to the age of fifteen years, passing her urine from the nipples, and getting rid of fæcal matters by vomiting. There are cases, moreover, in which it would seem that the mucous lining of the urinary bladder must have had a special power of secreting urine; the usual discharge having taken place to the end of life, when, as appeared by post-mortem examination, the kidneys were so completely disorganized that they could not have furnished it, or had been prevented by original malformation, or by ligature of the urethra, from discharging it into the bladder. A considerable number of these have been collected by Burdach.* In all the older statements of this kind, there is a deficiency of evidence that the fluids were really urinous, urea not having been obtained from them by chemical analysis, and the smell having been chiefly relied upon. The urinous odour, however, when distinct, is probably nearly as good an indication of the presence of the most characteristic constituent of human urine, as is the sight of the urea in its separated form. The passage of a urinous fluid from the skin has been frequently observed in cases in which the renal secretion was scanty; and the critical sweats, by which attacks of gout sometimes terminate, contain urates and phosphates in such abundance as to form a powdery deposit on the surface.—The metastasis of the *Biliary* secretion is familiar to every practitioner, as being the change on which *jaundice* is dependent. It is not, however, in every case of yellowish-brown discoloration of the tissues, that we are to impute such discoloration to the presence of biliary matter; and we can only safely do so, when we have at the same time evidence of concurrent disturbance of the biliary apparatus. The urinary apparatus then becomes the principal channel through which the biliary matter is eliminated; the urine becomes tinged with the colouring principle of

* "Zeitschrift für Physiologie," tom. ii. pp. 253, 254.

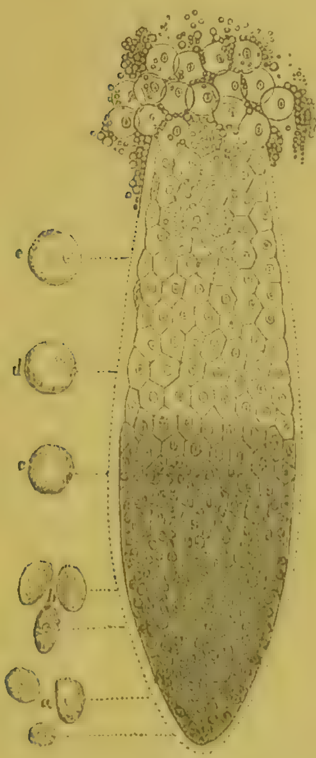
bile, being sometimes of a yellowish or orange hue, and sometimes of a brown colour with a considerable sediment; and the presence of the most characteristic constituents of the bile has been determined in the urine. The same result presents itself, when the biliary duct has been artificially obstructed by ligature. Other secretions have been found tinged with the colouring matter of bile: thus the pancreatic fluid has been seen of a yellow colour in jaundice; and the milk has presented not merely the hue, but the characteristic bitterness, of the biliary secretion. The cutaneous transpiration is not unfrequently so much impregnated with biliary matter, as to communicate the tinge to the linen covering the skin; and even the sputa of patients affected with bilious fevers have been observed to be similarly coloured, and have been found to contain biliary matter. The secretions of serous membranes, also, have been frequently seen to present the characteristic hue of bile; and biliary matter has been detected, by analysis, in the fluid of the pleural and peritoneal cavities. Biliary matter, however, when unduly present in the circulating current, is not removed from it by the secreting organs alone; for it seems to be withdrawn also in the ordinary operations of nutrition, entering into combination with the solid tissues. Thus, in persons affected with jaundice, we find the skin, the mucous and serous membranes, the lymphatic glands, the brain, the fibrous tissues, the cartilages, the bones and teeth, and even the hair, penetrated with the colouring matter of the bile, which they must have withdrawn from the blood, and which seems to have a particular affinity for the gelatinous tissues. It is impossible at present to say, however, to what extent the more characteristic ingredients of the bile are thus withdrawn from the blood; for the presence of its colouring matter cannot by any means be taken as an indication that its peculiar resinoid acids are also incorporated with the normal components of the tissues.

## 2. *The Liver.—Secretion of Bile.*

623. The *Liver* is probably more constantly present, under some form or other, throughout the entire animal series, than any other gland. Its form and condition vary so greatly, however, in different tribes, that, without a knowledge of its essential structure, we should be disposed to question whether any identity of character exists among the several organs which are regarded as Hepatic. It is, in fact, the presence of bile-secreting cells, that must be held to constitute a Liver; and these may be scattered over the general lining membrane of the alimentary canal, or may be restricted within follicles which are formed by depressions of it; these follicles, again, may be multiplied in some particular spot, so as to be aggregated into a mass, or may be extended into long tubes. In all the Invertebrata, however, the Liver is obviously conformable to the general type of glandular structures; the hepatic cells being in immediate relation with a basement-membrane, and being discharged upon a free surface. This will be readily understood from an examination of any one of the higher forms of it, such as that presented in the liver of the Crab, which, like the liver of the Mollusca generally, is a lobulated glandular mass, formed by the aggregation of a multitude of follicles with distinct cæcal terminations; these follicles discharging their secreted products

into cavities which occupy the centre of the lobules, whence they are collected by the ducts which discharge them into the alimentary canal. On a careful examination of these follicles, and a comparison of the size and contents of the cells at the bottom and towards the outlet, it becomes evident that the cells originate in the former situation, and gradually increase in size as they advance towards the latter. It is also to be observed that the cells which lie deepest in the cæcum (*a*, *b*) contain for the most part the yellow granular matter, which may be regarded as the proper biliary secretion; but as they increase in size, there is also an increase in the quantity of oil-globules which they contain (*c*), until past the middle of the follicle, where they are found full of oil, so as to have the appearance of ordinary fat-cells (*d*, *e*). From this it happens, that when an entire cæcum is examined microscopically, its lower half appears filled with a finely granular matter, intermingled with nucleated particles; and the upper half with a mass of fat-cells, whose nuclei are obscured by the oily particles.*—In Vertebrated animals, however, the Liver seems to be constructed upon a different plan; and the relation between the secreting cells of which its mass is composed, and the ducts by which their product is conveyed-away, is very difficult to determine satisfactorily except in certain Fishes, in whose liver the ducts may be shown to terminate in cæca filled with cells, as in the lower animals.† In ascending through the Vertebrated series, this organ presents a more and more solid parenchymatous texture, which strikingly contrasts with its loosely-lobulated racemose aspect in even the highest Invertebrata. This character is very obvious in the liver of Man, which is peculiarly firm and compact, and has less of connective tissue between its different parts, than is found in that of many other Mammalia. It is observable, moreover, in the Human liver, that certain parts are rudimentary which are elsewhere fully developed. Thus in the Carnivora and Rodentia, which present the most complex form of liver that we meet with among Mammalia, there are five distinct parts; namely, a 'central' or principal lobe, and a right and left 'lateral' lobe, each with its 'lobular appendage.' The whole mass of the liver of Man, which we are accustomed to describe as consisting of a 'right' and 'left' lobe, does in reality form but one (there being no real division between its two portions), which must be regarded as the 'central' lobe; the 'lobulus Spigelii' is the rudiment of a right 'lateral' lobe, and the 'lobulus caudatus' is its 'lobular appendage;'

FIG. 108.




One of the Hepatic cæca of *Astacus affinis* (Cray fish), highly magnified, showing the progress of development of the secreting cells from the blind extremity to the mouth of the follicle; specimens of these, in their successive stages, are shown separately at *a*, *b*, *c*, *d*, *e*.

* See Dr. Leidy's 'Researches into the Comparative Structure of the Liver,' in "Amer. Journ. of Med. Sci.," Jan. 1848.

† See Dr. T. Williams, in "Guy's Hospital Reports," 1846, p. 323.

but the left 'lateral' lobe, with its 'lobular appendage,' is altogether undeveloped.

624. In examining into the minute structure of the Liver, we shall first consider the peculiarities in the arrangement of its Blood-vessels and Ducts; for our present knowledge of which we are almost entirely indebted to Mr. Kiernan,* whose account of them will be here followed; his researches having been confirmed in all essential particulars by other Anatomists.—When the Liver is closely examined with the naked eye, it is seen to be made-up of a great number of small granular bodies, about the size of a millet-seed, of an irregular form, and presenting a number of rounded projecting processes upon their surfaces. These are commonly termed *lobules,* although by some Anatomists they are spoken of as *acini.* When divided longitudinally, they have a somewhat foliated appearance (Fig. 109), arising from the distribution of the Hepatic Vein; which, passing into the centre of each division, is termed the *intra*-lobular vein. The exterior of each lobule is covered by a process of the 'capsule of Glisson;' which is very dense in the Pig and other animals, but is so thin as to be almost undistinguishable in the Human liver. Its substance is composed of the minute ramifications of the before-mentioned vessels, arranged in the manner presently to be described; the spaces between which are filled with a parenchyma, composed of nucleated cells, like those shown in Fig. 114, B. The structure of each lobule, then, gives us the essential characters of the whole gland.—The lobules, when transversely divided, are usually found to present somewhat of a pentagonal or a hexagonal shape, the angles being somewhat rounded, so as to form a series of passages or *inter*-lobular spaces (Fig. 115): in these lie the branches of the Vena Portæ, and of the Hepatic Artery and Duct, from which are derived the plexuses that compose the lobules. Each lobule, when examined with the microscope, is found to be apparently composed of numerous minute bodies of yellowish colour, and of various forms, connected together by vessels; to these the name of *acini* was given by Malpighi; and to these, if they deserve a name, it ought to be restricted. They will be presently shown, however, to be nothing else than the irregular islets, left between the meshes of the plexus formed by the ultimate ramifications of the portal vein. The *Vena Portæ,* which is formed by the convergence of the veins that return the blood from the chylopoietic viscera, probably also receives the blood which is conveyed to the liver for the purposes of nutrition by the Hepatic Artery. Like an artery, it gradually subdivides into smaller and yet smaller branches; and at last it forms a plexus of vessels, which lie in the inter-lobular spaces, and spread with the freest

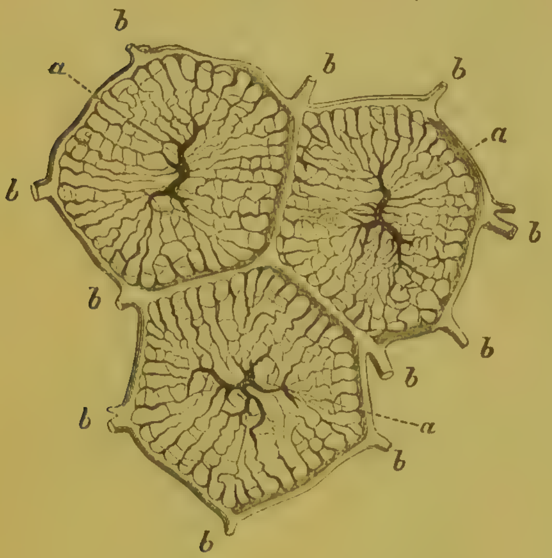
Fig. 109.


Connection of the *Lobules of the Liver* with the Hepatic Vein;—*a,* trunk of the vein; *b, b,* lobules depending from its branches, like leaves on a tree; the centre of each being occupied by a venous twig, the Intralobular Vein.

* "Philosophical Transactions," 1833.

inosculation throughout the entire Liver. To these vessels, the name of *inter*-lobular Veins was given by Mr. Kiernan. They ramify in the capsules of the lobules, covering with their ramifications the whole external surface of these; and then enter their substance. When they enter the lobules, they are termed *lobular* veins; and the plexus formed by their convergence from the circumference of each lobule towards its centre (where their ultimate ramifications terminate in those of the intra-lobular or hepatic vein), is designated as the *lobular venous plexus* (Fig. 110). In the islets of this plexus (the acini of Malpighi), the ramifications of the hepatic duct are distributed, in the manner to be presently described.—The *Hepatic Artery* sends branches to every part of the Liver, supplying the walls of the portal and hepatic veins, and of the hepatic ducts, as well as Glisson's capsule. The principal distribution of its branches, however, is to the Lobules, which they reach, in the same manner with the portal vessels and biliary ducts, by spreading themselves through the interlobular spaces. There they ramify upon the interlobular ducts, and upon the capsular surface of the lobules, which they then penetrate; their minuteness prevents their distribution within the lobules from being clearly demonstrable; but, as they enter along with the biliary ducts, there can be little doubt that, here as elsewhere, they are principally distributed upon the walls of these. As to the ultimate termination of the capillaries of the hepatic artery,—whether they enter the Portal plexus, or the Hepatic Vein,—there is a difference of opinion amongst anatomists; the former view being upheld by Kiernan, the latter by Müller. The question is a very interesting one in a physiological point of view; since, if the former account be the true one, the blood which is brought to the liver by the hepatic artery becomes subservient to the secretion of bile, only by passing into the portal plexus; whilst, if the latter be the correct statement, either the arterial blood is not at all subservient to the formation of bile, or the secretion can be elaborated from the arterial capillaries. The experiments of Mr. Kiernan have satisfactorily proved, that the intralobular or hepatic veins cannot be filled by injection from the hepatic artery, though they may be readily filled from the portal plexus; whilst, on the other hand, there is reason to believe, that a very fine injection into the hepatic arteries will find its way into the portal plexus.* It is certain that all the branches of the

Fig. 110.



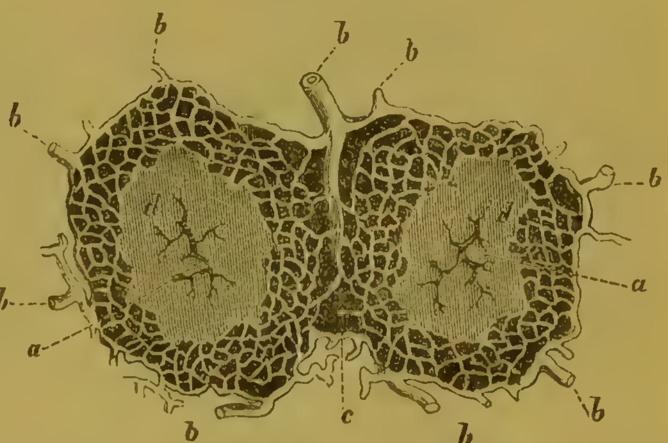

Horizontal section of three superficial Lobules, showing the two principal systems of *Blood-vessels*;—*a*, *a*, *intra*-lobular veins, proceeding from the Hepatic veins; *b*, *b*, *inter*-lobular plexus, formed by branches of the Portal vein.

* This is stated to have been the case in the injections of Lieberkühn, although Mr. Kiernan has not succeeded in effecting it.

hepatic artery, of which the termination *can* be ascertained, end in the vena portæ; a free capillary communication existing between their two systems of branches, on the walls of the larger blood-vessels and ducts. According to Müller, there is an ultimate plexus of capillary vessels, with which all the three systems freely communicate; but for this idea there is no adequate foundation; and it is inconsistent with the fact just stated, that injection into the hepatic artery does not return by the hepatic vein. The views of Mr. Kiernan upon this point have received important confirmation from the researches of Mr. Bowman on the circulation in the Kidney (§ 635).—It now only remains to describe the *Hepatic Veins*, the branches of which occupy the interior of the lobules, and are termed *intra*-lobular veins (*a*, *a*, Figs. 110 and 111). On making a transverse section of a lobule, it is seen that the central vessel is formed by the convergence of from four to six or eight minute venules, which arise from the processes upon the surface of the lobule. In the superficial lobules (by which term are designated those lobules which lie upon the exterior of the glandular substance, not only upon the surface of the liver, but also against the walls of the larger vessels, ducts, &c.) the intralobular veins commence directly from their surface; and the minute venules of which each is composed may be seen in an ordinary injection, converging from the circumference towards the centre, as in the transverse section of other lobules. The intralobular veins terminate in the larger trunks, which pass along the bases of the lobules, collecting from them their venous blood; these are called by Mr. Kiernan *sublobular* veins. The main trunk of the Hepatic Vein terminates in the ascending Vena Cava.

625. The *Hepatic Duct* forms, by its subdivision and ramification, an interlobular plexus very like that of the portal vein; but the anastomosis between the branches going to the different lobules is less intimate than that of the interlobular veins, and cannot be directly demonstrated; although Mr. Kiernan thinks that his experiments leave but little doubt of its existence,—a communication (which cannot be seen to be established by any nearer channel) being proved to exist between the right and left primary subdivisions of the duct. The interlobular ducts ramify upon the capsular surface of the lobules, with the branches of the portal vein and hepatic artery; they then enter its substance, and subdivide into minute branches, which are believed to anastomose with each other, and to form a reticulated plexus, termed by Mr. K. the *lobular biliary plexus* (Fig. 111). This

Fig. 111.




Horizontal section of two superficial Lobules, showing the interlobular plexus of *Biliary Ducts*;—*a*, *a*, intralobular veins; *b*, *b*, trunks of biliary ducts, proceeding from the plexus which traverses the lobules; *c*, interlobular tissue; *d*, parenchyma of the lobules.

plexus constitutes the principal part of the substance of the lobule; and when seen through the meshes of the portal plexus, gives rise to the appearance of cæcal terminations of ducts. No such terminations of these ducts have been traced, however, in the adult liver of any of the higher animals, although they are sufficiently evident in the embryonic condition. From the analogy of other organs, there would seem good reason to believe, that the ultimate ramifications of the hepatic ducts anastomose freely together, and that they form a network, in which their terminations are lost, as it were, without forming true cæca. This view of the matter finds confirmation in the curious fact pointed out by Mr. Kiernan, that, in the *left lateral ligament*, the essential parts of a lobule are found in the simplest form and arrangement. From the edge of the liver next to the ligament, numerous ducts emerge, which ramify between the two layers of peritoneum of which the ligament is composed. They are accompanied by branches of the portal and hepatic veins, and of the hepatic artery; which also ramify in this ligament, especially around the parietes of the ducts. These ducts, of which some are occasionally of considerable size, divide, subdivide, and anastomose with each other; and the meshes formed by the network of larger or excreting ducts, are occupied by minute plexuses of their ultimate ramifications or secreting ducts.—The more recent observations of Dr. Leidy (loc. cit.) harmonize precisely with the view promulgated by Mr. Kiernan, and seem to confirm the idea, that here, as elsewhere, the hepatic cells are enclosed in a limitary membrane. "The lobules are composed of an intertexture of biliary tubes (Fig. 112); and in the interspaces of the network the blood-vessels ramify and form among themselves an intricate anastomosis, the whole being intimately connected together by a combination of the white fibrous and the yellow elastic tissue. In structure,

Fig. 112.*

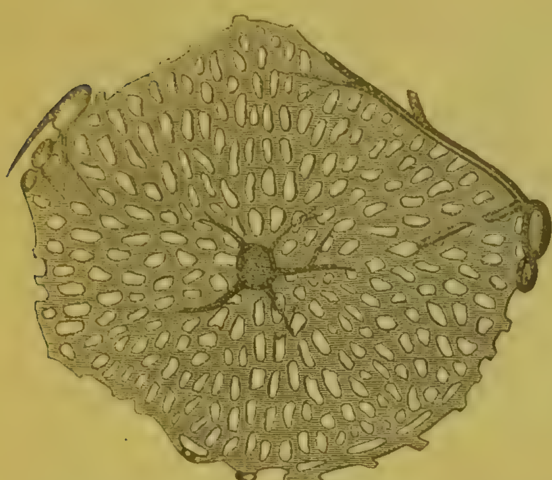
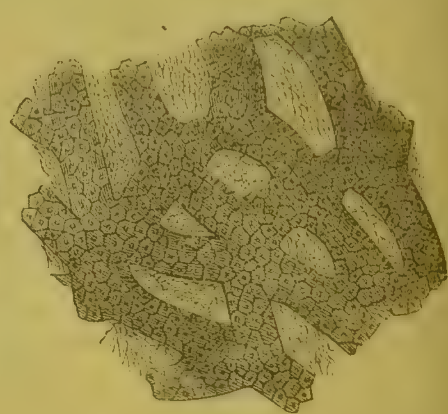


Fig. 113.†



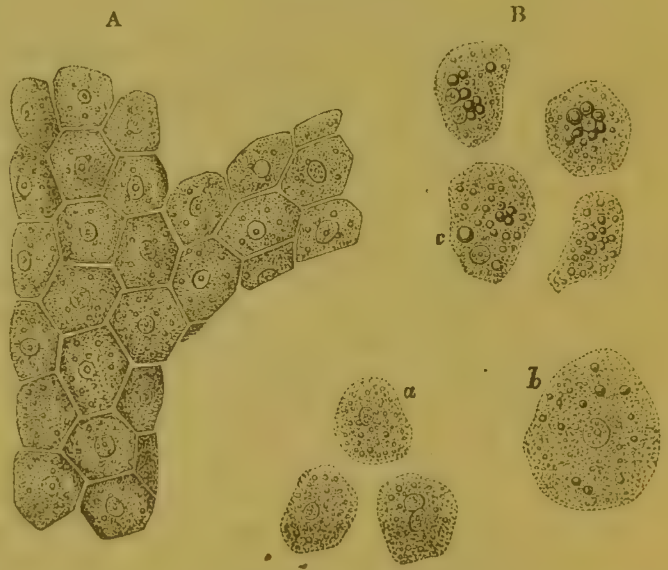
* Transverse section of a *Lobule* of the Human Liver, showing the reticular arrangement of the Bile-ducts, with some of the branches of the Hepatic Vein in the centre, and those of the Portal System at the periphery.

† A small portion of this section more highly magnified, showing the secreting cells within the tubes.

the biliary tubes (Figs. 113, 114) correspond with those of Invertebrata, consisting of cylinders of basement-membrane, containing numerous

secreting cells, and the only difference exists in the arrangement, the free tubes of the lower animals becoming anastomosed on forming an intertexture in the Vertebrata. The tubuli vary in size in an unimportant degree in different animals, and also in the same animal, being generally from two to two and a half times the diameter of the secreting cells. The tubes of one lobule are distinct from those of the neighbouring lobuli, or only communicate indirectly by means of the trunks of hepatic ducts, originating from the tubes, and lying in the interspaces of the lobuli. The secreting cells (Fig. 114, B) are irregularly angular or polygonal in form, from mutual pressure, and line the interior surface of the tubes. They vary in size in a moderate degree in different animals, and also in the same animal, appearing to depend upon certain conditions of the animal and liver." * The subsequent observations of Dr. Natalis Guillot † are mainly to the same effect. He has not been able, however, to distinguish membranous parietes around these canals; and he considers that they are simply channelled-out in the parenchyma of the liver, the particles of which form its sole borders. Professor Retzius, however, by a particular method of preparation, has been able to demonstrate the existence of a basement-membrane surrounding the biliary cells, and forming a plexus of hepatic ducts, as described by Dr. Leidy. ‡

FIG. 114.




A, portion of a *Biliary Tube*, from Human Liver, with the secreting cells:—B, secreting cells detached, *a*, in their normal state, *b*, a cell more highly magnified, showing the nucleus and distinct oil-particles, *c*, in various stages of fatty degeneration.

626. The *biliary cells* of the Human liver (Fig. 114, B) are usually of a flattened spheroidal form, and from 1-1500th to 1-2000th of an inch in diameter. Each of them presents a distinct nucleus; and the cavity of the cell is occupied by yellow amorphous biliary matter, usually having one or two large adipose globules, or five or six small ones, intermingled with it (*a*, *b*). The size and number of these, however, vary considerably, according to the nature of the food, the amount of exercise recently taken, and other circumstances. If an animal be very fat or

* See "American Journal of the Medical Sciences," Jan. 1848.—Dr. Leidy does not specify the mode in which his preparations have been made; but we understand that his plan is to *dry* a small portion of injected liver, then to make as thin a slice of this as possible, and to examine this slice when restored to its original condition by moisture.

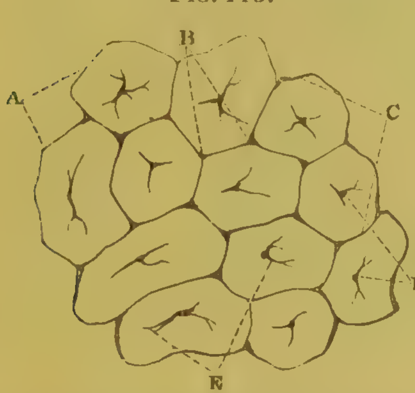
† "Annales des Sciences Naturelles," Mars, 1848.

‡ See the account of his researches in "Müller's Archiv.," 1850. His method consists in first macerating a piece of liver in ether, then drying it, cutting thin sections from it in this condition, and soaking these in water until they become transparent.—For a very different view of the structure of the Liver, see Dr. Handfield Jones's papers in the "Philosophical Transactions" for 1846 and 1849.

well fed, especially with farinaceous or oleaginous substances, the proportion of adipose particles is much greater than in an animal moderately fed and taking much exercise (*c*). The size of the globules varies from that of mere points, scarcely distinguishable from the granular contents of the cells except by their intense blackness, up to one-fourth of the diameter of the cell. The finely-granular matter is the portion from which the colour of the cell is derived; it seems to fill the space not occupied by the oil-globules; and it often obscures the nucleus, so that the latter cannot be distinguished until acetic acid is added, which makes the granular matter more transparent without affecting the nucleus.—A still greater accumulation of adipose particles in the biliary cells, gives rise, as was first pointed-out by Mr. Bowman,* to the peculiar condition termed 'fatty liver,' (§ 628.)†

627. The knowledge of the distribution of the Biliary ducts, and of the two chief systems of Blood-vessels, in the lobules of the Liver, has enabled Mr. Kiernan to give a most satisfactory explanation of appearances, by which Pathological anatomists had been previously much perplexed. When the liver is in a state of *Anæmia* (which rarely happens as a natural condition, although it may be induced by bleeding an animal to death), the whole substance of the lobules is pale, as represented in Fig. 115. In general, however, the liver is more or less congested at the moment of death; and this congestion may manifest itself in several ways. The whole substance may be congested; in which case the lobules present a nearly uniform dark colour throughout their substance, their centres being usually more deeply-coloured than the margins. An appearance more frequently offered after death, however, is that represented at Fig. 116, and termed by Mr. Kiernan the *first* stage of *Hepatic Venous* congestion. In this, the isolated centres of the lobules alone present the colour of sanguineous congestion; and the surrounding substance varies from a yellowish-white, yellow, or greenish colour, according to the quantity and quality of the bile which it contains. This accumulation of the blood in the hepatic veins, and the emptiness of the portal

Fig. 115.



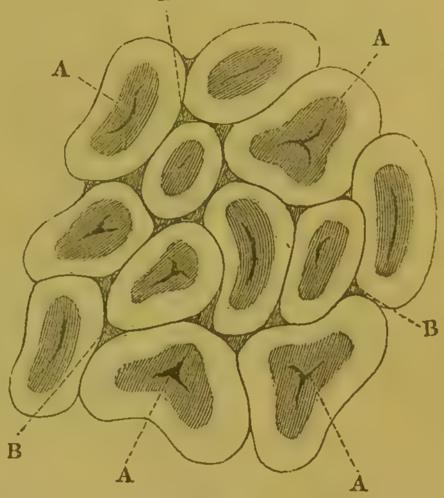

A, angular lobules in a state of *Anæmia*, as they appear on the external surface of the liver; B, interlobular spaces; C, interlobular fissures; D, interlobular veins, occupying the centres of the lobules; E, smaller veins, terminating in the central veins.

* "Medical Gazette," Jan. 1842.

† It has been recently maintained by Dr. Handfield Jones ("Medical Times," Jan. 31, 1852, p. 122), that "the cells of the liver are not the constant and necessary agents in the secretion of bile, and that the occurrence of this secretion in them is rather to be viewed as an accidental if not a pathological phenomenon; the real function of the cell being to produce the sugar out of the blood supplied to them, which is absorbed and carried off by the hepatic vein." The arguments adduced in support of this opinion are, that in perfectly healthy livers of animals, bile is not ordinarily to be seen in the contents of the cells, while it is very common in those of persons who have died of various diseases; and that in extracts made of the parenchymata of various livers, Pettenkofer's test gave very little or no evidence of the presence of biliary matter.—A far larger amount of research is necessary, however, to establish such a novel and (at first sight) very improbable view.

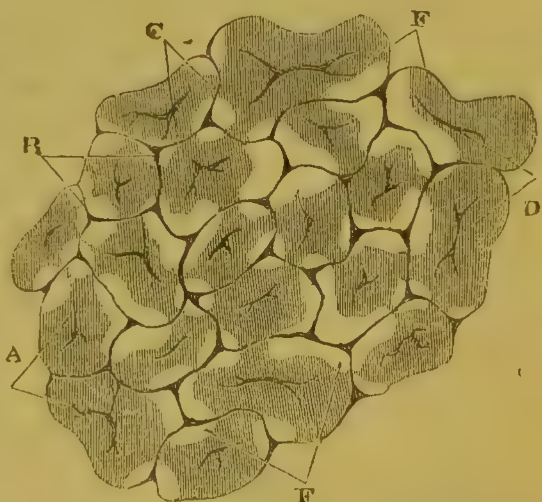
plexus, seem due to the continuance of capillary action after the general circulation has ceased, a circumstance to which we find an exact parallel in the emptiness of the systemic arteries, and the fulness of the veins, after most kinds of death.—In the *second* stage of Hepatic Venous congestion, the accumulation of blood is found not only in the intralobular veins, but even in parts of the portal or lobular venous plexus. The parts which are freest from it are those surrounding the interlobular spaces; so that the non-congested substance here appears in the form of circular or irregular patches, in the midst of which the spaces and fissures are seen (Fig. 117).* Although the portal as well as the hepatic venous system is thus involved in this form of congestion, yet, as the obstruction evidently originates in the latter, the term given by Mr. Kiernan is still applicable; and it is important to distinguish this appearance from that next to be described. The second stage of Hepatic Venous congestion very commonly attends disease of the heart, and other disorders in which there is an impediment to the venous circulation; and in combination with accumulation in the biliary ducts, it gives rise to those various appearances, which are known under the name of dram-drinkers' or nutmeg liver. — The other form of partial congestion arises from an accumulation of blood in the portal veins, with a reverse condition of the hepatic or intralobular veins; in this condition, which Mr. K. designates as *Portal Venous congestion*, the marginal portions of the lobules are of deeper colour than usual, and form a continuous network, the isolated spaces between which are occupied by the non-congested portions (Fig. 118). This is a very rare occurrence; having been seen by Mr. K. in children only.—These differences fully explain the diversity of the statements of different anatomists, as to the relative position of the so-called *red* and *yellow* substances; for it now appears,

FIG. 116.




A, rounded lobules in *first* stage of *Hepatic Venous congestion*, as they appear on the surface of the liver; B, interlobular spaces and fissures.

FIG. 117.

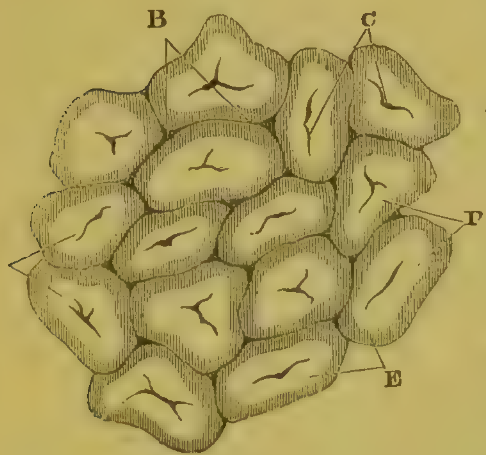



A, lobules in the *second* stage of *Hepatic Venous congestion;* B, and C, interlobular spaces; D. congested intralobular veins; E, congested patches, extending to the circumference of the lobules; F, non-congested portions of lobules.

* This very common aspect of the Liver, which presents numerous modifications, has been a source of great perplexity to those who have studied the minute anatomy of this organ, and has even led Anatomists of the highest eminence into serious errors. See Mr. Erasmus Wilson, "Cyclop. of Anat. and Physiol.," vol. iii. pp. 185, 186.

that the *red* substance is the *congested* portion of the lobules, which may be either interior or exterior, or irregularly disposed; whilst the *yellow* is the *non-congested* part, in which the biliary plexus shows itself more or less distinctly.—Another very interesting form of Pathological change in the aspect of the Liver, which the knowledge of the structure of the lobules enables us to comprehend, is that to which the name of *Cirrhosis* has been given. This has been erroneously attributed to the presence of a new deposit, analogous to that of tubercular matter; but it is really due to atrophy and partial congestion in the liver itself. It is described by Laennec as usually presenting itself in small masses, varying in size from a cherry-stone to a millet-seed, and scattered through the substance of the liver. When these are minute and closely set, they impart what appears at first to be a uniform brownish-yellow tint to the divided surface of the liver; but when the tissue is more attentively examined, their separation becomes evident.

Fig. 118.




A, lobules as they appear on the surface in a state of *Portal Venous congestion;* B, interlobular spaces and fissures; C, intralobular hepatic veins, containing no blood; D, the central portions in a state of anæmia; E, the marginal portions in a congested state.

These small masses are not distinct lobules in a variable state of hypertrophy (as supposed by Cruveilhier); but small uncongested patches, composed of parts of several adjoining lobules, and having one or more interlobular spaces for a centre; and the biliary plexuses of these, being filled with bile, give them their yellow colour. On the other hand, there is an atrophy, more or less complete, of the portions of the substance of the liver intervening between them; so that the bulk of the whole organ is much diminished, very commonly to one-half, and sometimes to one-third of its original size.

628. Among the most frequent of the pathological changes which the assistance of the Microscope enables us to discern in the biliary cells, is that engorgement with adipose particles, which is observable in the condition of the organ known as 'fatty liver' (Fig. 119). This state having been frequently observed in individuals who have died of phthisis or other diseases of the lungs involving deficient respiration, has been imputed to a vicarious action of the liver, which (as was supposed) made an effort thus to discharge the hydrocarbonaceous matters that should normally be eliminated by the lungs. But such a view is inconsistent with various facts, which show (as Mr. Paget has justly remarked)* that the fatty liver is an inactive organ, one which is discharging *less* than its ordinary function, and that the accumulation of fat in its

Fig. 119.


Hepatic Cells gorged with Fat: *a*, atrophied nucleus; *b*, adipose globules.

* 'Lectures on Nutrition,' &c. in "Medical Gazette," 1847, vol. xl., p. 235.

ells is rather to be considered as a mark of 'fatty degeneration.' For the uclei disappear, the proper colouring-matter of the bile can no longer be listinguished, the liver increases in size owing to the tardy or obstructed emoval of its cells, and its paleness indicates a slow and defective supply of blood; moreover the fatty liver presents itself in many cases in which here has been no deficiency of respiration, and is frequently absent in hthisical subjects; and there is no evidence whatever, that the organ when n this state discharges any unusual amount of fat into the alimentary canal. Still there can be little doubt that the accumulation of adipose matter in he biliary cells is favoured by deficiency of respiration, since this will tend o increase the quantity which the circulating fluid contains. Throughout the Animal series, moreover, a marked relation of reciprocity is liscernible between the amount of fat contained in the Hepatic apparatus, nd the activity of the respiratory function; thus in Birds, the biliary ells scarcely contain any fatty particles, whilst in Reptiles and Fishes hey are loaded with them; and nearly the same difference may be seen etween the biliary cells of Insects and those of Crustacea and Mollusca. —Various other alterations, however, have been noticed. Dr. T. Williams nentions,* that, in a case of obstruction of the ductus choledochus y malignant disease, which occasioned complete interruption to the assage of bile, and consequent jaundice, scarcely an entire nucleated ell could be discovered by attentive examination of a large part of the rgan. Nothing more than minute free particles of fat, and free floating morphous granular matter, could be detected. He further states that, a a case of fever, the hepatic cells were found to be almost entirely destitute of fatty particles; and that in what is known as 'granular liver,' e granules (which have much the appearance of tubercles) consist of ells, which strongly resemble the ordinary cells of the parenchyma of the ver in every respect, except that they are almost or completely destitute of yellow contents. Similar observations have been also recorded by r. G. Budd.†—In two cases of jaundice examined by Mr. Gulliver, the epatic cells were gorged with biliary matter; some of them to such n extent, that they had become nearly opaque. Perhaps if this condition had continued, these cells would have been all ruptured, and e state of the organ would have resembled that described by Dr. Villiams.

629. Previously to birth, the Liver is the only decarbonising organ in e system, the lungs being at that time inert; and nearly the whole of the lood returning from the placenta passes through this organ, before proeeding to the heart, to be distributed by it to the body generally. The ver of the fœtus, moreover, is considerably larger in proportion than that the adult; and its functional importance is obviously great. There n be no question that the secretion of bile is actively taking place uring the latter part (at least) of fœtal life; for a large accumulation of presents itself in the intestinal canal of the new-born infant,—the *econium* having been found by the analyses of Simon‡ and of Frerichs§ be chiefly made up of the characteristic components of the biliary

* "Guy's Hospital Reports," 1843.

† See his Treatise on "Diseases of the Liver," 2nd edit., pp. 211, 247, &c..

‡ "Animal Chemistry," translated by Dr. Day, vol. ii. p. 367.

§ Dr. Day's 'Report on Chemistry,' in "Ranking's Half-yearly Abstract," vol. iii. p. 314.

secretion.—As soon, however, as the placental circulation is cut off, and the Lungs of the infant come into play, the supply of blood transmitted to the liver is almost immediately lessened; this diminution being usually made very evident within a short time after birth, by the comparative paleness of the substance of the gland. It has been proposed to give this fact a practical bearing, in those judicial inquiries which are directed to the determination of the question, whether or not an Infant has respired after birth; it having been conceived, that the diversion of the current of blood from the Liver to the Lungs, consequent upon the first inspiration, would be sufficient to make a certain difference in their relative weights, if that inspiration had taken place. More careful and extended observations, however, have satisfactorily proved that, although an increase in the weight of the Lungs, and a diminution of that of the Liver, are generally found to exist after respiration has been fully established, they are not by any means constantly produced when the inspirations have been feeble, as they frequently are for some hours or days after birth; whilst, on the other hand, it is not uncommon to meet, in infants that have not breathed, with Lungs as heavy, and Livers as light, as in the average of those which have respired.*

630. We have now to consider the conditions, under which the secretion of Bile takes place; and one of the most important of these, is the character of the Blood with which the organ is supplied. We have seen that there is anatomical reason for the belief, that the blood supplied by the hepatic artery is not directly concerned in the secretion; but that it first serves for the nutrition of the organ, and then, passing into the portal system (in the same manner as does the blood of the mesenteric and other arteries), forms part of the mass of venous blood, from which the secreting cells elaborate their product. This view is borne out by the results of experiment, and of pathological observation. For, if the Vena Portæ be tied, the secretion of bile still continues, though in diminished quantity; and several cases are on record, in which, through a malformation, the vena portæ terminated in the vena cava without ramifying through the liver, and in which secretion of bile took place,—evidently from the blood of the hepatic artery, which had become venous by circulating through the substance of the liver; and this blood appears† to have passed into the ramifications of the umbilical vein, which formed a plexus in the lobules, exactly resembling the ordinary portal plexus. It must be remembered, however, that in all these instances, the *arterial* Blood will become abnormally charged with the elements of bile; since the blood of the chylopoietic viscera, from which it ought to have been separated, returns to the heart without undergoing any such purification; and the secretion of bile from the blood supplied by the hepatic artery, under such circumstances, cannot, therefore, be considered as proving that the arterial blood is ordinarily concerned in the secretion to the same degree. —The fact that this secretion is normally formed from *venous* blood, is a strong indication that one purpose of its separation is the removal of a portion of the products of the disintegration of the tissues: and that a large amount of hydrocarbonaceous matter will remain to be excreted,

* See Dr. Guy, in "Edinb. Med. and Surg. Journ.," vols. lvi. and lvii.

† This, at least, was found to be the case, in the only instance in which the Liver was examined with sufficient care. See Kiernan, loc. cit.

after the constituents of urea have been subtracted from those of albumen or gelatin, has been already pointed out (§ 91, VI.). But, again, the position of the Liver in regard to the mesenteric vessels is such, that all the new alimentary materials which are received by them must pass through it and be submitted to its action, before they enter the general current of the circulation; and there are several circumstances which render it probable that it exercises a depurative as well as an assimilating power over these, and that whilst it assists in preparing for nutrition those azotized substances which are capable of being applied to that purpose, and also transforms non-azotized matters into compounds which are more ready to undergo combustion and are thus better fitted for sustaining the heat of the body by respiration, it also eliminates certain substances whose passage into the general circulation would be injurious.—This is assuredly the case with regard to copper and certain other mineral poisons (§ 89); and it seems also to be true with respect to pus, which, when taken-up from ulcers in the intestinal walls, is stopped in the liver, and not unfrequently gives rise to abcesses in its substance.*

631. When from any cause the secretion of Bile is *suspended*, the substances at the expense of which it is formed accumulate in the Blood; and their excrementitious character is strikingly demonstrated by the disturbance of other functions, especially those of the Nervous system, which then ensues. When the suppression is complete, the patient suddenly becomes jaundiced, the powers of that system are speedily lowered (almost as by a narcotic poison), and death rapidly supervenes.† When the secretion is diminished, but not suspended, the same symptoms present themselves in a less aggravated form. It is probable that much of the disorder in the functions of the brain, which so constantly accompanies deranged action of the digestive system, is due to the less severe operation of the same cause; namely, the partial retention within the blood, of certain constituents of the bile, which should have been eliminated from the circulating fluid. Such an abnormal accumulation, which may depend either on a deficiency in the functional activity of the liver, or on an excess of the excrementitious matters brought to it for elimination, is habitual in some persons; and it produces a degree of indisposition to bodily or mental exertion, which it is difficult to counteract. More, probably, is to be gained in such cases by the regulation of the diet, especially the reduction of its hydro-carbonaceous components, and by active exercise (which, by augmenting the respiration, will promote the elimination of any superfluity of this kind through the lungs), than by continually

* See Dr. G. Budd's "Treatise on Diseases of the Liver," 2nd edit., Chap. ii., sect. 1.

† See Dr. Alison in "Ed. Med. & Surg. Journ.," vol. xliv; and Dr. Budd, Op. Cit., Chap. iii. From the evidence collected by Dr. Budd, he is led to think it probable that the cerebral nptoms are not due to the simple retention of the materials of Bile; but depend upon some tamorphosis which these undergo whilst circulating with the blood, whereby a more xious poison is generated. For the general symptoms of suppressed secretion may have own themselves for some time, before any serious disturbance occurs in the cerebral funcns; and this may supervene very suddenly, and be fatal in a few hours (p. 263). The logy of Uræmia (§ 637) seems to afford some confirmation to this view; but it must be ne in mind as a possible explanation of the phenomena, and one which has evidence in its our, that the kidneys, by a vicarious action, remove the most poisonous of the retained ary matters; and that it is only when *they* can no longer effect this, that the results the accumulation of these matters begin to show themselves in the perversion of the ctions of the nervous centres.

inciting the liver to increased functional activity, by medicines which have a special power of temporarily augmenting its energy.—The *re-absorption* of Bile into the blood, as seen in ordinary cases of jaundice dependent upon the obstruction of the biliary ducts, does not act on the general system in a manner nearly so injurious, as the *retention* of the matters at the expense of which it is formed has been shown to do;* in fact, much of the disturbance which then ensues, may be attributed to the disorder of the digestive function, which is consequent upon the stoppage of the flow of bile into the intestinal canal (§§ 453, 454). And when it is further remembered that the greater part of the bile which passes into the intestinal canal is ordinarily destined for re-absorption (§ 457), it seems fair to conclude that the matters which accumulate in the blood when the secreting action of the liver is suspended, are not in the same condition with those which are received back into it after being submitted to that action; and that the liver, therefore, not merely separates them, but exercises a certain *transforming* agency upon them, as it is known to effect upon other constituents of the blood which passes through it (§ 472).

632. Bile is a viscid, somewhat oily-looking liquid, of a greenish-yellow colour, and very bitter taste, followed by a sweetish after-taste. It is readily miscible with water, and its solution froths like one of soap. The proportion of solid matter which it contains is usually from 9 to 12 per-cent; and nearly the whole of this consists of substances peculiar to Bile.—The following are the general results of the analyses made by Berzelius, of Human Bile, and of that of the Ox:—

| | Man. | Ox. |
|---|---|---|
| Water . . . . . . . | 90·44 | 92·84 |
| Biliary matter . . . . . | 8·00 | 5·00 |
| Mucus of the gall-bladder . . . | ·30 | ·23 |
| Soda . . . . . . | ·41 | |
| Chloride of sodium, and extractive . . | ·74 | 1·50 |
| Phosphates and sulphates of soda and lime . | ·11 | ·43 |
| | 100·00 | 100·00 |

In the Biliary matter, according to the researches of Strecker (which are undoubtedly the most accurate and satisfactory that have been hitherto made), the following substances may be distinguished:—*Glycocholic acid* (the *cholic* of Strecker and of many former authors), which is its principal organic constituent, united for the most part with soda, but with small and variable quantities of potash and ammonia (§ 68);—*Tauro-cholic acid* (the *choleic* acid of Strecker, also known as *bilin*), which also is united with alkaline bases (§ 69);—*Cholesterin* (§ 43), the proportion of which in healthy bile is usually very small;—and *Bile-pigments* (§ 70),

* Dr. Budd mentions several cases (Op. cit. pp. 209–227) in which the passage of bile into the intestines was entirely prevented by the complete closure of the ductus communis, and in which, nevertheless, life was prolonged for many months; in one of these cases, the jaundice first occurred in a woman four months pregnant, who nevertheless bore a living child at the full period, and suckled it up to the time of her death, which happened when the child was three months old.—In all these cases, death seemed to result from gradual exhaustion, consequent upon the imperfect assimilation of food, rather than from any toxic agency; and this even when the liver was in such a state of disorganization, that its functional activity must have been suspended for some time before death.

of which also the proportion is usually small. It is remarkable that notwithstanding the comparatively minute proportion in which these two last substances exist in ordinary bile, Cholesterin should usually be the principal ingredient of the biliary concretions which are frequently found in the gall-bladder and bile-ducts; and that the bile-pigment should also occasionally accumulate, so as to form solid masses which consist of little else.* It would appear from this, that the peculiar resinous acids of the bile are far more readily re-absorbed than are its other ingredients; and this corresponds with the results of experiments upon the contents of the alimentary canal, which show that whilst the colour of the fæces is chiefly due to the presence of bile-pigment, the conjugated acids are scarcely to be recognized.—The quantity of Bile ordinarily secreted by the liver, the circumstances which favour or retard its production, the mode in which it is discharged into the intestine, and the purposes which it answers in the digestive process, have all been considered in a previous chapter (§§ 453, 454); and it now only remains to point out, that the fact of the performance of this operation during fœtal life, as shown by the accumulation of biliary matter in the intestinal canal at birth (§ 629), is a clear indication of the truly excrementitious matter of this product. Its separation from the blood during intra-uterine life can have no reference to the process of digestion, which is not then taking place; nor can it be subservient to that of respiration, which has not commenced; but it must be regarded, like the elimination of urea, as a necessary means of removing from the blood those products of the disintegration of the tissues, which are taken back into the circulation even when the life of the being is most purely vegetative; and this necessity arises from that limitation to the existence of each individual part, which is most remarkable when the processes of growth and development are taking place with the greatest rapidity.

633. If, now, we bring together all the facts at present known, with regard to the actions performed by the Liver, they appear to justify the following conclusions with respect to its offices.—1. That the Liver is essentially an organ of excretion, designed to remove from the Blood those hydrocarbonaceous products of the disintegration of the tissues, which cannot be converted into sugar or fat so as to be prepared for direct elimination by the respiratory organs. 2. That in doing this, it converts these excrementitious matters into the glyco-cholic and tauro-cholic acids; substances which have a certain utility in the digestive process, and which, after ministering to that function, are capable of being re-absorbed, and of undergoing oxidation; whereby the greater part of their components are carried-off in the form of carbonic acid and water by the lungs, the remainder (chiefly the alkaline bases, with the sulphur of the taurine, which is converted into sulphuric acid) being eliminated by the kidneys.—3. That not only by the separation of biliary matter from the blood, and by the operation of this upon the alimentary substances, but also by the change in the constituents of the blood itself, the Liver aids in preparing materials for the combustive process. For it converts all

* The cholesterin and bile-pigment (which forms a definite compound with lime) are held in solution in healthy bile by the tauro-cholic acid. Hence it seems likely that the production of the biliary concretions which are composed of these substances, is due either to a relative deficiency of tauro-cholic acid, or to a decomposition of that substance in the gall-bladder.

forms of saccharine matter derived from the food into 'liver-sugar,' the form which is most favourable to oxidation; and it would seem capable also of generating this sugar from protein-compounds, or from certain products of their decomposition (§ 46). And it exercises a similar transforming power upon fatty matter; generating the peculiar 'liver-fat,' either from other oleaginous or from saccharine substances supplied by the food, or, as it would also appear, from protein-compounds, or from the products of the early stages of their retrograde metamorphosis (§ 40). —In all the foregoing actions, the Liver is subservient to the Respiratory function; but in a mode very different from that formerly propounded by Prof. Liebig,* who represented the Liver as destined to prepare by secretion the materials adapted for the sustenance of the combustive operation. For it is quite certain that if the whole of the solid biliary matter poured into the intestine were re-absorbed, it could furnish but a small proportion (probably not more than one-twelfth) of the total amount of hydrocarbon which is eliminated by the lungs: and the preparation of the liver-sugar and liver-fat in the blood itself is evidently the far more important part of the office of the Liver, as regards the Respiratory function.—4. But the Liver also aids, if the statements of M. Bernard on this point be correct, in the assimilation of the histogenetic materials, which have been newly absorbed from the digestive cavity; the raw albumen being converted by its means into a form more suitable for transmission through the system in the current of the circulation, and even fibrin being generated at its expense (§§ 167, 169). It must be admitted, however, that there are many points in the function as well as in the structure of the Liver, which still remain to be cleared-up.

### 3.—*The Kidneys.—Secretion of Urine.*

634. The *Kidneys* cannot be regarded as inferior in importance to the Liver, when considered merely as excreting organs; but their function only consists in separating from the blood certain effete substances which are to be thrown off from it, and has no direct connection with any of the nutritive operations concerned in the introduction of aliment into the system. The following are the points in the minute structure of these organs, which are of most importance in their Physiological relations.† The distinction between the *cortical* and *medullary* parts of the Kidney essentially consists in this,—that the former is by far the most vascular, and the plexus formed by the tubuli uriniferi seems to come into the closest relation with that of the sanguiferous capillaries, so that it is probably the seat of the greater part of the process of secretion; whilst the latter is principally composed of tubes, passing in a straight line from the former towards their point of entrance into the ureter. The adjoining figure (Fig. 120) represents the appearances presented by a portion of an injected Kidney, as seen by the naked eye, and under a low magnifying

* "Chemistry applied to Animal Physiology," 1842.

† See especially Mr. Bowman's Memoir in the "Philosophical Transactions," 1842; also Goodsir in "Edinb. Monthly Journal," 1842; Gerlach, Bidder, and Kölliker, in "Müller's Archiv.," 1845; Toynbee in "Med.-Chir. Trans.," 1846; Johnson in "Cyclop. of Anat. and Phys.," art. 'Ren.'; Gairdner in "Edinb. Monthly Journal," 1848; and Frerichs, "Die Bright'sche Nierenkrankheit und deren Behandlung," 1851.

power. The tubuli uriniferi, in passing outwards from the calices, increase in number by divarication to a considerable extent, as shown in Fig. 122, but their diameter remains the same. When they arrive in the cortical substance, their previously straight direction is departed from, and they become much convoluted. The closeness of the texture formed by their interlacement with the blood-vessels, renders it difficult to obtain a clear view of their mode of termination; but they seem to inosculate with each other, so as to form a plexus, with free extremities here and there (Fig. 122); the number of these free extremities, however, does not appear to be nearly equal to that of the uriniferous tubes themselves.* The tubuli are lined with an epithelium, the cells of which are irregularly roundish or polyhedral in form (Fig. 121); each cell contains a nucleus;

Fig. 120.*


Fig. 121.†

* Portion of the *Kidney* of a new-born infant:—A, natural size; *a, a*, Corpora Malpighiana, as dispersed points in the cortical substance; *b*, papilla.—B, a smaller part magnified; *a, a*, Corpora Malpighiana; *b*, tubuli uriniferi.

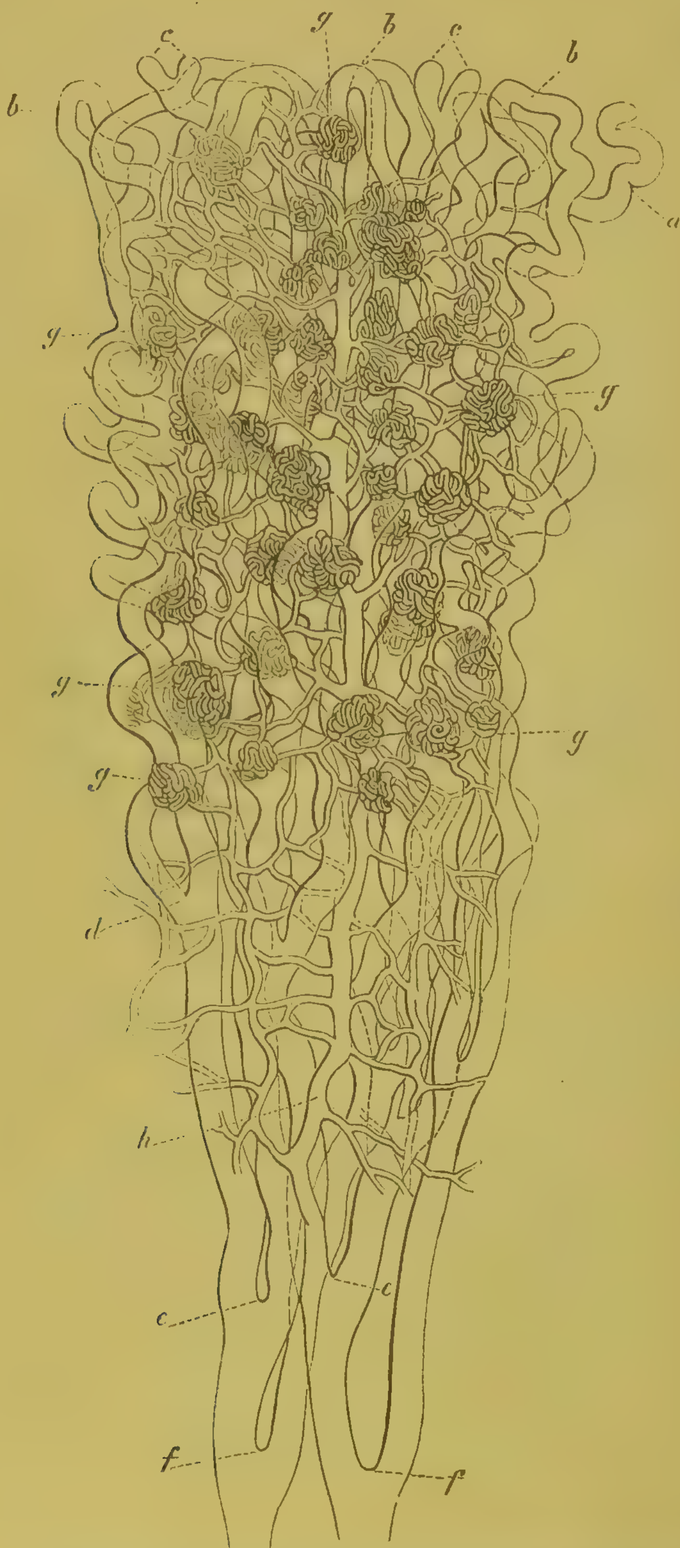
† Portion of one of the *tubuli uriniferi*, from the kidney of an adult; showing its tesselated epithelium.

and in its interior there is ordinarily to be seen a little finely-granular matter, with a few minute fat-globules clustered round the nucleus. The cell-wall is remarkable for its delicacy, and is one of the first structures to undergo decomposition; and after its destruction, free nuclei, interspersed among amorphous granules, alone remain in the interior of the tubules. The epithelial cells are arranged more or less regularly on the interior of the basement-membrane, in such a manner that a free channel is left in the centre of each tubule.—Scattered through the plexus formed by the blood-vessels and uriniferous tubes, a number of little dark points may be seen with the naked eye, to which the designation of Corpora Malpighiana has been given, after the name of their discoverer. Each one

* In Mr. Bowman's opinion, *all* the free extremities of the tubuli uriniferi include Corpora Malpighiana; and the appearance of cæcal terminations, such as those represented at *a* and *c*, Fig. 122, he regards as an optical illusion, caused by a change in the direction of the tubuli, which occasions them to dip away suddenly from the observer.

of these, when examined with a high magnifying power, is found to consist of a convoluted mass of minute blood-vessels (Fig. 122, *g*); and

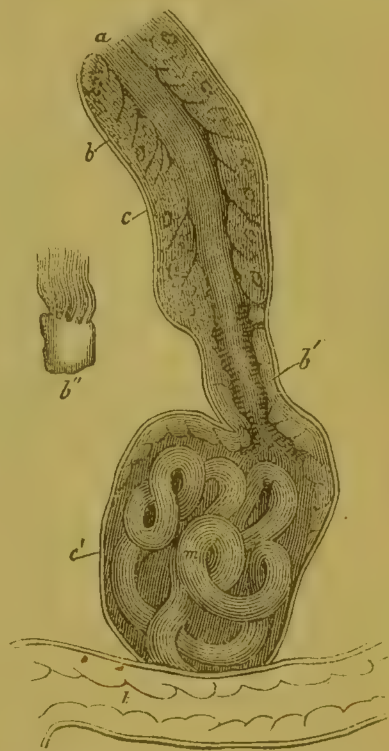
FIG. 122.




A small portion of the *Kidney*, magnified about 60 times:—*a*, supposed cæcal extremity of a tubulus uriniferus; *b*, *b*, recurrent loops of tubuli; *c*, *c*, bifurcations of tubuli; *d*, *e*, *f*, tubuli converging towards the papilla; *g*, *g*, *g*, Corpora Malpighiana, seen to consist of convoluted knots of blood-vessels, connected with a capillary net-work; *h*, arterial trunk.

this is included in a flask-like dilatation of one of the tubuli uriniferi (Fig. 123). According to Mr. Bowman, this dilatation proceeds only from the termination of the tubulus; and this seems to be usually the case, although it seems not improbable that it may sometimes be a lateral diverticulum, as described by Gerlach (loc. cit.) The epithelium, which elsewhere lines the tube, is altered in appearance where the tube is continuous with this capsular dilatation (Fig. 123, *b′*); being there more transparent, and furnished with cilia (as shown at *b″*), which in the Frog may be seen for many hours after death, in very active motion, directing a current down the tube. Further within the capsule, this epithelium becomes excessively delicate, and sometimes disappears altogether. The surface of the Malpighian tuft is often seen to be studded with nuclear particles, which suggest the idea that it is covered by an epithelial layer; and hence Gerlach, followed by other anatomists, has maintained that the flask-shaped dilatation of the tubulus uriniferus is not perforated by the blood-vessels which form the Malpighian tuft, but is reflected over it. It appears probable, however, that these nuclear particles, really belong to the walls of the vessels; and the most careful examination has failed to detect any such reflexion. On this as on all other points of importance, therefore, Mr. Bowman's original description proves to be unassailable.*

Fig. 123.



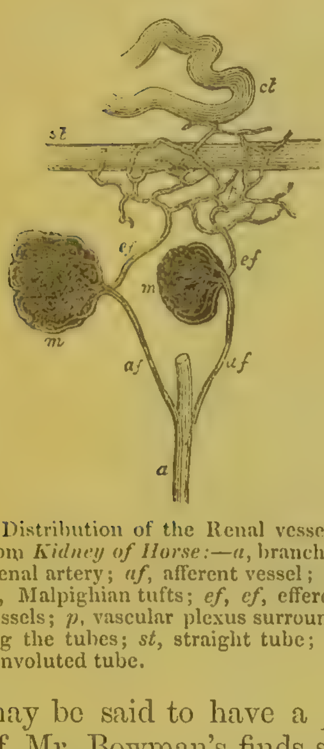

Uriniferous Tube, Malpighian Tuft, and Capsule, from *Kidney of Frog*:—*a*, cavity of the tube; *b*, epithelium of the tube; *b′*, ciliated epithelium of the neck of the capsule; *b″* detached epithelium-scale; *c*, basement-membrane of tube; *c′*, basement-membrane of capsule; *m*, convoluted capillaries of the Malpighian tuft.

635. The Circulation of Blood through the Kidney presents a very remarkable peculiarity. The supply is derived in Man (as in other Mammalia) direct from the *arterial* system; though in Fishes and Reptiles the urinary apparatus is connected, as well as the biliary, with the *portal venous* system, and even in Birds a portion of its blood is derived from the latter. But although this organ is supplied from the renal artery, yet it is not to its proper secretory apparatus that the blood of that artery is distributed in the first instance; for, on entering the kidney, this vessel speedily and entirely divides itself into minute twigs, which are the *afferent* vessels of the Malpighian tufts (Fig. 124, *af*). After it has pierced the capsule, each twig dilates; and suddenly divides and subdivides itself into several minute branches, terminating in convoluted capillaries, which are collected in the form of a ball (*m*, *m*); and from

* The *a priori* improbability that the basement-membrane of a glandular tubule or follicle should be thus penetrated by blood-vessels, has been entirely removed by the discovery that such penetration does take place in other cases, as the Peyerian glandulæ (§ 456) and the Corpora Malpighiana of the Spleen (§ 482).

the interior of the ball, the solitary *efferent* vessel, *e f*, arises, which passes out of the capsule by the side of the single afferent vessel. This ball seems to lie loose and bare in the capsule, being attached to it only by its afferent and efferent vessels (Fig. 123, *m*). The *efferent* vessels, on leaving the Malpighian bodies, separately enter the plexus of capillaries, *p*, surrounding the tubuli uriniferi, *st*, and supply that plexus with blood; from this plexus the renal vein arises.—Thus there is a striking analogy between the mode in which the tubuli uriniferi are supplied with blood, for the purpose of elaborating their secretion, and the plan on which the hepatic circulation is carried on. For as the secretion of the Liver is formed from blood conveyed to it by one large vessel, the vena portæ, which has collected it from the venous capillaries of the chylopoietic viscera, and which subdivides again to distribute it through the liver, so the secretion of the Kidney is elaborated from blood which has already passed through one set of capillary vessels, those of the Malpighian tufts; this blood is collected and conveyed to the proper *secreting* surface, however, not by one large trunk (which would have been a very inconvenient arrangement), but by a multitude of small ones, the *efferent* vessels of the Malpighian bodies, which may be regarded as collectively representing the vena portæ, since they convey the blood from the systemic to the secreting capillaries. Hence the Kidney may be said to have a *portal* system within itself.—This ingenious view of Mr. Bowman's finds support from the fact, that in Reptiles the *efferent* vessels of the Malpighian bodies (which receive their blood, as elsewhere, from the renal artery) unite with the branches of the vena portæ, to form the secreting plexus around the tubuli uriniferi. Here, therefore, the blood of the secreting plexus has a double source, the vessels which supply it receiving their blood in part from the capillaries of the organ itself, and in part from those of viscera external to it; just as, in the Liver, the secreting plexus is supplied in part by the nutritive capillaries of the organ itself, which receive their blood from the hepatic artery, and in part by the blood conveyed from the chylopoietic viscera through the vena portæ.

Fig. 124.




Distribution of the Renal vessels; from *Kidney of Horse*:—*a*, branch of Renal artery; *af*, afferent vessel; *m*, *m*, Malpighian tufts; *ef*, *ef*, efferent vessels; *p*, vascular plexus surrounding the tubes; *st*, straight tube; *ct*, convoluted tube.

636. These admirable researches of Mr. Bowman on the structure of the Malpighian bodies, and on the vascular apparatus of the Kidney, have thrown great light upon the mode in which the Urinary secretion is elaborated. One of the most remarkable circumstances attending this excretion, in the Mammalia particularly, is the large but variable quantity of *water*, which is thus got rid of,—the amount of which bears no constant proportion to that of the solid matter dissolved in it. The Kidneys, in fact, seem to form a kind of regulating valve, by which the quantity of water in the system is kept to its proper amount. The amount of exhalation from the Skin, which, with that from the Lungs, is the other principal

means of removing superfluous liquid from the blood, is liable to be greatly affected by the temperature and degree of humidity of the air around (§ 647): hence, if there were not some other means of adjusting the quantity of fluid in the blood-vessels, it would be subject to continual and very injurious variation. This important function is performed by the Kidneys; which allow such a quantity of water to pass into the urinary tubes, as may keep the *pressure* within the vessels at a nearly uniform standard. The quantity of water which is passed off by the Kidneys, therefore, will depend in part upon that exhaled by the Skin; being greatest when this is least, and *vice versâ:* but the quantity of solid matter to be conveyed away in the secretion has little to do with this; being dependent upon the amount of *waste* in the system, and upon the quantity of surplus azotized aliment which has to be discharged through this channel.—The Kidney contains two very distinct provisions for these purposes. The *cells* lining the tubuli uriniferi are probably here, as elsewhere, the instruments by which the *solid* matter of the secretion is elaborated; whilst it can scarcely be doubted that the office of the Corpora Malpighiana is to allow the transudation of the superfluous fluid through the thin-walled and naked capillaries of which they are composed. "It would indeed," Mr. Bowman remarks (Op. cit., p. 75), "be difficult to conceive a disposition of parts more calculated to favour the escape of water from the blood, than that of the Malpighian body. A large artery breaks-up in a very direct manner into a number of minute branches; each of which suddenly opens into an assemblage of vessels of far greater aggregate capacity than itself, and from which there is but one narrow exit. Hence must arise a very abrupt retardation in the velocity of the current of blood. The vessels in which this delay occurs are uncovered by any structure. They lie bare in a cell, from which there is but one outlet, the orifice of the tube. This orifice is encircled by cilia, in active motion, directing a current towards the tube. These exquisite organs must not only serve to carry forward the fluid which is already in the cell, and in which the vascular tuft is bathed; but must tend to remove pressure from the free surface of the vessels, and so to encourage the escape of their more fluid contents."—Here we see the essential difference which exists, between the *vital* agency concerned in the true secreting process, and the *physical* power which occasions fluid exhalation or transudation. This difference is precisely the same as that which exists between the *vital* act of selective absorption, and the *physical* operation of endosmose or imbibition. By Imbibition and Transudation, certain fluids may pass through organic membranes, in the dead as well as in the living body; and this passage depends merely upon the physical condition of the part, in regard to the amount and the nature of the fluid it contains, and the permeability of its tissues. Not only does water thus transude, but various substances that are held in complete solution in it, especially albuminous and saline matter: it is in this manner that the Blood absorbs fluids from the digestive cavity (§ 464), and pours out the serous fluid which occupies the interspaces of the areolar tissue and the serous cavities. The transudation of the watery portion of the blood is much increased by any impediment to its flow through the vessels, and also by any causes that produce a diminished resistance in their walls.

637. The nature and purposes of the Urinary secretion, and the alterations which it is liable to undergo in various conditions of the system, are much better understood than are those of the Bile; this is owing, in great part, to the two circumstances, that it may be readily collected in a state of purity, and that its ingredients are of such a nature as to be easily and definitely separated from each other by simple chemical means. There can be no doubt that the chief purpose of this excretion, is to remove from the system the effete azotized matters, which the blood takes up in the course of the circulation, or which may have been produced by changes occurring in itself. This is evident from the large proportion of Nitrogen contained in the solid matter dissolved in it; and from the crystalline form presented by much of this solid matter when separated,—a form which indicates that its state of combination is such, as to prevent it from conducing to the nutrition of the system. The injurious effects of the retention of the components of the Urinary secretion in the Blood, are fully demonstrated by the results of its cessation; whether this be made to take place experimentally (as by tying the renal artery), or be the consequence of a disordered condition of the kidney. The symptoms of *Uræmia* (as this condition has been appropriately termed) are altogether such as indicate the action of a specific poison upon the Nervous system; affecting either the Brain or the Spinal Cord separately, or both together. In the first form, a state of stupor comes on rather suddenly, out of which the patient is with difficulty aroused; and this gradually deepens into complete coma, with fixed pupils and stertorous breathing, just as in ordinary kinds of narcotic poisoning. In the second form, convulsions of an epileptic character, frequently affecting the whole muscular system, suddenly occur; but there is no loss of consciousness. In the third form, coma and convulsions are combined. It has been generally supposed that these results are attributable to the accumulation of *urea* in the blood; but clinical observation affords sufficient evidence, that there is no constant relation between the severity of these symptoms and the amount of urea in the circulating system;* and experiment has determined that the other constituents of the urine do not exert any more potent influence.† It seems probable, then, that some substance formed at the expense of the normal constituents of urine, rather than either of these substances themselves, is the real poisonous agent in cases of Uræmia; and very cogent evidence has been adduced by Prof. Frerichs, in proof of his idea that the symptoms of this disorder arise from the conversion of the Urea in the circulating current into Carbonate of Ammonia, by the agency of a suitable ferment; so that, however great may be the accumulation, it does not give rise to any serious consequences, unless this ferment be also present. Two series of experiments are described by him as supporting this doctrine; the first showing that in cases of uræmic intoxication, a resolution of urea into carbonate of ammonia is actually

* It has been remarked by Bright, Christison, G. O. Rees, and Frerichs, that urea may often be obtained in considerable quantity from the blood of patients suffering under 'Bright's disease,' who were at the same time free from all nervous symptoms.

† Thus Frerichs (as Bichat, Courten, and Gaspard had before done) repeatedly injected from 20 to 40 grammes of filtered human urine, sometimes even with the addition of urea, into the veins of animals, without any ill effects resulting.

ıking place, ammonia being found in the expired air when the first ·ymptoms make their appearance, and in the blood and in the contents f the stomach after death; and the second proving that the injection of ırbonate of ammonia into the circulating current induces a train of ymptoms essentially corresponding with those of uræmia, stupor and onvulsions occurring either separately or conjointly.*—It seems not nprobable that, as in the case of the retention of Bile in the Blood ; 631), many of the minor as well as of the severer forms of sympaıetic disturbance, connected with disordered secretion from the kidney, e due to this directly poisonous operation of the decomposing constiıents of the urine, upon the several organs whose function is disturbed; ıd that many complaints, in which no such agency has been until ecently suspected,—especially Convulsive affections arising from a disrdered action of the nervous centres,—are thus due to the insufficient imination of Urea from the Blood.†

638. In order to form a correct opinion of the state of the Urinary ecretion in morbid conditions of the system, it is desirable to be acıainted with every leading particular regarding its normal character.—resh healthy Urine is a perfectly transparent, amber-yellow-coloured quid, exhaling a peculiar but not disagreeable odour, and having a itterish saline taste. In all natural conditions of the Human system ven when a vegetable diet is used), the urine possesses a well-marked cid reaction. When it is left to itself for some time, slight nebulæ, onsisting of mucus, are formed in it; and these gradually descend to the ottom. Soon afterwards, an unpleasant odour is developed; instead of ı acid, an alkaline reaction is presented, in consequence of the decompotion of the urea into carbonate of ammonia; and a precipitation of ırthy phosphates then takes place. A turbidity may occur, however, on ıe simple cooling of the urine, without any such departure from its ormal composition as would properly constitute disease; this being due the precipitation of urates of soda and ammonia, under the conditions rmerly specified (§ 56). If the urine be turbid, however, when it is ıssed from the body, having a temperature of 98° or 100°, it must be onsidered as abnormal. The average *Quantity* of urine passed during e 24 hours, has been variously estimated: it differs, of course, with e amount of fluid ingested, and it is influenced also by the external mperature; a much smaller amount of the superfluous fluid of the ody being set free from the skin in winter than in summer, and a larger oportion being carried off by the kidneys. Probably we shall be pretty ear the truth, in estimating the amount (with Dr. Prout) at from about ) oz. in summer, to 40 oz. in winter, for a person who does not drink ore than the simple wants of nature require.—The *Specific Gravity* mes to be a very important character, in various morbid conditions of the ine: and it is therefore desirable to estimate it correctly. This also is ıble, of course, to the same causes of variation; since, when the same

* On this subject, the chapter on 'Uræmia' in the admirable treatise of Frerichs "Die ight'sche Nierenkrankheit und deren Behandlung," should be especially consulted.

† Of the truth of this view, which was propounded by the Author in the first edition of is work, many illustrations have been since afforded; among the most interesting of which, the very frequent coincidence of 'Bright's disease' with Puerperal Convulsions, first pointed t by Dr. Lever.

amount of solid matter is dissolved in a larger or smaller quantity of water, the specific gravity will be proportionably lower or higher. The average, according to Dr. Prout, in a healthy person, taking the whole year round, is about 1020; the standard rising in summer (on account of the greater discharge of fluid by perspiration) to 1025; and being lowered in winter to 1015. Simon, however, states the average specific gravity at no more than 1012. It will depend, in each individual case, upon the amount of fluid habitually ingested, as compared with that dissipated by cutaneous exhalation; and it will also vary with the period that has elapsed since the last introduction of liquid into the stomach. From these and other causes, the proportion of solid matter in 1000 parts of Urine may vary from 20 to 70; and hence the various recorded analyses of this liquid present very wide diversities in the proportions of its solid constituents. These discrepancies, however, being chiefly due to the fluctuating amount of water, become very much less (as Simon* pointed out) when we calculate the proportion which each principal component bears to 100 of solid residue; as is shown in the following Table:—

| | Berzelius. | Lehmann. | Simon. | Marchand. |
|---|---|---|---|---|
| Urea . . . . | 45·10 | 49·68 | 33·80 | 48·91 |
| Uric Acid . . . | 1·50 | 1·61 | 1·40 | 1·59 |
| Extractive matter, Ammonia-salts, and Chloride of Sodium. | 36·30 | 28·95 | 42·60 | 32·49 |
| Alkaline Sulphates . . . | 10·30 | 11·58 | 8·14 | 10·18 |
| Alkaline Phosphates . . | 6·88 | 5·96 | 6·50 | 4·57 |
| Phosphates of Lime and Magnesia . | 1·50 | 1·97 | 1·59 | 1·81 |

We shall presently find the causes of some of the variations even here shown, to lie in the nature of the ingesta, and in the amount of exercise taken by the individual.

639. The most important of those organic constituents of the Urine, whose presence may be directly traced to the metamorphosis of the azotized components of the tissues and of the blood, is evidently that which, from its being the principal cause of the characteristic properties of the secretion, is termed *Urea.* This substance, as already shown (§ 52), exists preformed in the Blood; being generated by the retrograde metamorphosis of Muscular tissue (probably through the intermediation of creatine or of uric acid), and also by similar changes in the unassimilated portions of the Blood itself.†—The amount of Urea excreted in the 24

* "Animal Chemistry," translated by Dr. Day, vol. ii. p. 146.

† A new and easy method of determining the amount of Urea in Urine has lately been introduced by Prof. Liebig. It is founded on the fact that urea forms with pernitrate of mercury two compounds, one with 2, the other with 4 equiv. of peroxide of mercury. The latter is almost insoluble; and therefore, by adding to urine pernitrate of mercury, from a solution of known strength, the urea may be precipitated and its quantity determined in a few minutes. All the phosphoric acid in the urine, however, must first have been precipitated by barytes; which will also, of course, throw down its sulphuric acid. The presence of a chloride prevents the action of the pernitrate on the urea, converting it into a perchloride; hence the chloride of sodium always contained in the Urine must be allowed-for, before the quantity of Urea can be determined. The appearance of the precipitate shows when all the chlorine present has been taken into combination with the mercury; so that the quantity of the pernitrate added to produce it gives that of the common Salt, while the quantity *afterwards* required to throw down the whole Urea gives the amount of that substance. (See Prof. Gregory's "Hand-book of Organic Chemistry," p. 509; and Dr. Martin Barry's communication in the "Lancet," April 17, 1852.)

ours has been made the subject of examination by M. Lecanu;* and ne following are his results as deduced from a series of 120 nalyses:—

| | Minimum. | Mean. | Maximum. |
|---|---|---|---|
| By Men† . . . | 357·51 grs. | 433·13 grs. | 510·36 grs. |
| By Women . . | 153·25 „ | 295·15 „ | 437·06 „ |
| By Old Men (84 to 86 years) . | 61·08 „ | 125·22 „ | 295·15 „ |
| By Children of eight years . | 161·78 „ | 207·99 „ | 254·20 „ |
| By Children of four years . | 57·28 „ | 69·55 „ | 81·83 „ |

; is very interesting to perceive, in this table, how large an amount of rea is excreted by children; and how small a quantity in proportion to eir bulk, by old men. This corresponds precisely with the rapidity of terstitial change at different periods of life. (See CHAP. III., Sect. 3). he quantity of Urea secreted at any given period of life seems to depend ainly on two conditions; namely, the degree of muscular exertion preously put forth, and the amount of azotized matter ingested as food. hus Prof. Lehmann ascertained that, by the substitution of *violent* for *oderate* exercise, the quantity of Urea was raised from $32\frac{1}{2}$ to $45\frac{1}{3}$ parts; id Simon found that, by two hours' violent exercise, the proportion of e urea in the urine passed half an hour subsequently, was double that ntained in the morning urine. Again, Prof. Lehmann has shown that e amount of Urea excreted daily, when no azotized matter was taken-in food, and when the excretion was simply a measure of the 'waste' the tissues, was not above *half* that excreted when an ordinary mixed et was employed, and only about *two-sevenths* of that which was passed en the diet was purely animal. The recent experiments of Prof. schof are to the same effect; for he found that a large dog secreted, th mixed food, from 230 to 300 grains of urea daily; with flesh diet, 2 grains; and when fed on intestines and gelatine, no less than 1110 ains daily. This last statement confirms the inference to which the jection of a solution of Gelatin directly into the blood appears to lead 399); namely, that urea may be formed directly from the metamoriosis of this substance, and probably, therefore, from the disintegration the gelatigenous as well as of the albuminous tissues.—Next in imrtance to urea, among the organic products of the metamorphosis of e azotized constituents of the tissues or of the blood, but ordinarily aring a very small proportion to it in quantity, is *Uric acid.* It has en shown (§ 57) that the formation of this substance is probably terior to that of urea; and we shall see that its proportion in the ine is augmented under the same conditions as regards food (§ 640). 1 the other hand, there is reason to think that exercise, by augmentg the respiration, tends to diminish the proportion of uric acid in the

* "Journal de Pharmacie," tom. xxv.

† According to Prof. Bischof, of Giessen, who has employed Prof. Liebig's method of imating the amount of urea in Urine (described in the preceding note), the quantity linarily excreted daily by a healthy man is not less than 830 grains, or nearly 2 ounces oirdupois. If this be correct, the estimates of Lecanu are far below the truth, his *mean* for n being only 433 grains, or little more than half the estimate of Bischof. Still the above le will have a certain value; since all the amounts stated in it were obtained by the same thod, and may therefore be fairly compared with each other. The speedy publication of of. Liebig's process "in a form adapted for easy and accurate use by medical men" has been mised; and it is to be hoped that a large body of valuable facts will then be collected.

urine, by converting it into urea. The circumstances that most favour the *genesis* of uric acid in the system, therefore, and its increased proportion in the urine if there be no obstacle to its elimination, are a highly azotized diet and inactive habits; whilst the reduction of the azotized portion of the diet to what is really wanted for the nutrition of the system, and the promotion of the respiration by active exercise, tend to the reduction of the proportion of this component. The *precipitation* of uric acid (usually in combination with alkaline bases), which frequently takes place on the cooling of the urine, must not be regarded as indicative of the presence of an unusual amount of this substance; since it may depend upon a variety of other conditions (§ 56). There are many diseases, however, especially those of a febrile nature, in which the presence of an excess of uric acid is a very marked symptom; there is usually, at the same time, a reduction in the proportion of urea; and thus it would seem that, with perhaps an augmented tendency to disintegration of the tissues, there is an incapacity for the performance of that higher process of oxidation, which is requisite for the genesis of urea; so that a larger proportion of the products of the 'waste' passes off in the state of uric acid, as in animals whose respiration is feeble.—This view derives support from the fact, that *Hippuric acid*, which is only to be found in extremely minute proportion in healthy Human urine, and the composition of which indicates that it is to be regarded as a result of very imperfect oxidation (§§ 58, 59), undergoes a marked increase under the same circumstances, and especially when obstructed action exists in either of the other great emunctories, the lungs, liver, or skin, so that a larger amount of carbonaceous matter is thrown upon the kidneys for elimination; for in this case, also, there is a deficiency in the normal amount of urea.—Although the presence of *Creatine* and *Creatinine* in the Urine, the former in very small proportion, but the latter in considerably larger amount, is now a well-established fact, the actual quantities ordinarily excreted, and the circumstances which favour their increase and diminution, have not yet been determined. From the considerations formerly adduced (§§ 60, 61), it seems likely that Creatine is one of the first products of the disintegration of muscular tissue, and that a portion of the urea eliminated in the urine, as well as of the greater part (if not the whole) of the creatinine, is generated at its expense.—The presence of *Lactic acid* in the Urine, although by no means infrequent, must be regarded as exceptional. We have seen that a constant genesis of this substance is taking place in the body, not merely as a product of the metamorphosis of the saccharine matters employed as food, but also as one of the results of the disintegration of the azotized tissues (§§ 48–50); but that the respiratory process affords the ordinary channel for its removal; so that it is only when its production is excessive, or when there is some obstruction to its elimination by the lungs, that it makes its appearance in the urine. These conditions are so often present in disease, that Lactic acid is far more commonly present in abnormal than in normal states of the secretion.—The *Extractive Matters* of the Urine, as already pointed out (§ 64), are made up of a variety of different compounds, our knowledge of which is gradually being extended. Among the substances which rank under this head in the ordinary analyses of Urine, are creatine, creatinine, and hippuric acid; and others

e being successively determined. Thus Städeler has shown that the ›tractive' of the Urine of the Cow contains a peculiar azotized com-›und, and several volatile non-azotized acids, analogous to, and in one ›stance absolutely identical with, the products of the imperfect oxidation › wood or coal.* And Prof. Ronalds has shown that the 'extractive' of ›uman urine ordinarily contains a sulphurized and a phosphorized com-›und, which serve for the excretion of sulphur and phosphorus in an ›oxidized state.† The *Urine-Pigment*, again, has been to a certain ›tent separated as a definite compound from the 'extractive,' especially › the researches of Heller (§ 64). On the whole, we may say that with ›e exception of Creatine and Creatinine, all the known constituents of ›e 'Urinary extractive' are substances which are rich in carbon and ›mparatively poor in nitrogen; so that their increase will be favoured › an excess of carbonaceous food, an imperfect action of the liver, and a ›w degree of respiration;‡ whilst, on the other hand, a highly-azotized ›et, especially if combined with active exercise, will tend to their re-›uction. This view is confirmed by the results of Prof. Lehmann's ›periments, which were performed with a view to determine the influence › diet upon the constitution of the Urine.

640. In the *first* series of these experiments, Prof. Lehmann adopted › ordinary *mixed* diet; but he took no more solid or liquid aliment, than ›s needed to appease hunger or thirst, and abstained from fermented ›inks. Every two hours he took exercise in the open air, but he avoided ›moderate exertion of every kind. The average result of the examina-›n of the Urine passed under these circumstances, for fifteen days, is ›ven in the first line of the subsequent table.—In a *second* series of ›periments, Prof. L. lived for twelve days on an exclusively *animal* diet; ›d for the last six of these, it consisted solely of eggs. He took 32 eggs ›ily; which contained 2929 grains of dry albumen, and 2431 grs. of ›ty matters; or about 3532 grs. of carbon, and 465½ grs. of azote. The ›nount of Urea is shown, in the second line of the table, to have under-›ne a very large increase; and it contained more than five-sixths of the ›ole azote ingested.—In a *third* series of experiments, Dr. L. lived for ›elve days on a *vegetable* diet; and its effect upon the solid matter of ›e Urine is shown in the third line of the table.—In a *fourth*, he lived › two days upon an *unazotized* diet, consisting entirely of pure farina-›ous and oleaginous substances; so that the azotized matter of the Urine ›ust have been solely the result of the disintegration of the tissues. It › seen to undergo a very marked diminution, under this regimen; as is ›own in the fourth line of the table. His health was so seriously affected, ›wever, by this diet, that he was unable to continue it longer.

* See Dr. Gregory's "Hand-book of Organic Chemistry," p. 450.

† See "Philosophical Transactions," 1846, pp. 461—464.

‡ This is particularly obvious in cases in which the functions of the Liver are imperfectly ›formed. For there is first to be observed an increase in the ordinary Urine-pigment ›hich contains 58½ per cent. of carbon), giving a high colour to the secretion, and causing › addition of a few drops of hydrochloric acid to the warmed fluid to develope a fine ›nson or purple hue. If the inactivity of the liver increase, a deposit of *purpurine* (a sub-›nce which contains 62½ per cent. of carbon) is thrown down (§ 64). And the complete ›est of the elimination of bile is marked by the appearance of the proper Bile-pigment in › urine. (See Dr. Golding Bird's 'Lectures on Therapeutics,' in "Med. Gaz.," 1848, › xlii. p. 229).

| | *Solid Matters.* | *Urea.* | *Uric Acid.* | *Extractive Matters and Salts.* |
|---|---|---|---|---|
| I. Mixed diet | 1047·14 grs. | 501·76 grs. | 18·26 grs. | 196·65 grs. |
| II. Animal diet | 1350·07 „ | 821·37 „ | 22·82 „ | 112·89 „ |
| III. Vegetable diet | 914·66 „ | 347·10 „ | 15·77 „ | 295·95 „ |
| IV. Non-Azotized diet | 643·53 „ | 237·90 „ | 11·34 „ | 264·48 „ |

The following inferences are drawn by Prof. Lehmann, from these experiments:—1. Animal articles of diet augment the *Solid matters* of the Urine. Vegetable substances, and still more such as are deprived of azote, on the contrary, diminish it.—2. Although Urea is a product of decomposition of the organism, yet its proportions in the urine depend also on the food, for we find that a richly-azotized diet considerably augments its quantity. In the above experiments, the proportion of the Urea to the other solid matters was as 100 to 116 on a mixed diet; as 100 to 63 on an animal diet; as 100 to 156 on a vegetable diet; and as 100 to 170 on a non-azotized diet.—3. The quantity of *Uric acid* depends less on the nature of the diet, than on other circumstances; the differences observed in it being too slight to warrant us in ascribing them to the former cause.—4. The Protein-compounds, and consequently the azote of the food, are absorbed in the intestinal canal; and what is not employed in the formation of the tissues, is thrown off by the Kidneys in the form of Urea or Uric acid; these organs being the chief, if not the sole, channel through which the system frees itself of its excess of azote.—5. The urine contains quantities of *Sulphates* and *Phosphates* proportional to the azotized matters which have been absorbed; and the proportion of these salts is sensibly increased under the use of a large amount of those substances.—6. In the same circumstances, the *Extractive matters* diminish, while their quantity is increased by the use of vegetable diet; a fact which proves the influence of vegetable aliment over the production of these matters in the urine.—7. The urine after the use of animal food has a strong acid reaction, but contains little or no lactic acid and no hippuric acid. Under a vegetable diet there is more lactic acid, but it is united to bases. The largest production of lactic acid is under a non-azotized diet; and most of it is then combined with ammonia. Therefore the lactic acid eliminated with the urine, is in great part the product of non-azotized substances not entirely assimilated; but it results also in part from the decomposition of the azotized substances entering into the composition of the body and the food.—8. The Kidneys not only separate certain constituent parts of the organs, which have become inadequate for the maintenance of life, but they also expel the superfluous nutritive matters that may have been absorbed.*

641. Besides its organic materials, the Urine contains a considerable amount of *Saline* matter; the excretion of which, in a state of solution, appears to be one of the principal offices of the Kidney. Various saline compounds are continually being introduced with the food; and others are formed within the system, by the oxidation of the Sulphur and Phosphorus of the tissues or of the food, and by the combination of the sulphuric and phosphoric acids thus formed, with alkaline and earthy bases which the food may contain, usually in a state of combination with

* "Journ. für praktische Chemie," 1842–3; see also "Simon's Animal Chemistry," translated by Dr. Day, vol. ii. pp. 156—164; and Prof. Lehmann's "Lehrbuch der Physiologischen Chemie," band ii. p. 447.

weaker acids which are otherwise disposed-of. Thus the Saline compounds found in the urine are to be regarded as partly proceeding from the retrograde metamorphosis of the materials of the tissues, after these have served their purpose in the economy, and partly from that of such components of the food, as, being superfluous, do not undergo organization. But the Kidney also serves as the channel for the elimination of saline compounds introduced into the system *per se;* these being sometimes normally present in the body, but ingested in too large an amount, as is often the case with common Salt; whilst, on the other hand, they may be altogether foreign to the composition alike of its solids and its fluids. —The *Alkaline Sulphates* usually constitute, as we have seen (§ 638), about 10 per cent of the whole solid matter of the Urine. Being always in solution, however, they never make their presence known by the formation of sediments, and are only to be detected by chemical tests. The causes which influence their amount have been carefully studied by Dr. Bence Jones; who has shown that they vary (like urea) with the amount of food ingested, and with the degree of nervo-muscular activity put forth; as might be anticipated from the fact, that, under ordinary circumstances, the sulphuric acid is entirely formed within the system, by the oxidation of the sulphur of the protein-compounds, the bases being furnished by the alkaline carbonates or phosphates of the blood, whose source has been already considered (§ 83). When sulphuric acid or soluble sulphates are taken into the system *per se,* they partly find their way out of it by the Kidneys (§ 88); the proportion of sulphuric acid in the urine being for a time augmented, although the increase is not considerable until some hours have elapsed after the introduction of these substances into the stomach.*—The amount of *Alkaline Phosphates* (§ 84) in the Urine is usually about half that of the alkaline sulphates. The acid of these also is ordinarily generated within the system, by the oxidation of the phosphorus originally introduced in the protein-compounds; and thus, as in the case of the sulphates, the quantity of them which is excreted by the urine bears a certain relation to the amount of these compounds ingested as food, and also to the amount of muscular tissue which has undergone disintegration by exercise. But it further appears that there is a special relation between the *quantity* of the alkaline phosphates in the urine, and the amount of disintegration of the *nervous* tissue (§ 361); as might have been suspected from the fact, that this tissue is distinguished by the very large proportion of phosphorus, united with fatty acids, which it contains (§ 345). And a marked increase of these salts is observed in those inflammatory diseases of the brain, in which there is reason to believe that an unusually rapid disintegration of its texture is taking place.†—The *Earthy Phosphates* usually bear but a small proportion to the Alkaline; but their presence in the urine comes to be of great importance, with reference to the precipitates which they form in particular conditions of that secretion. From the researches of Dr. Bence Jones (loc. cit.)

* Dr. Bence Jones in "Philosophical Transactions," 1849.

† See Dr. Bence Jones's valuable series of Papers, in the "Philosophical Transactions" for 1845, 1847, and 1850, and in the "Medico-Chirurgical Transactions" for 1847 and 1850. It is curious to observe, that whilst the increase in the alkaline phosphates in Inflammatory affections of the nervous centres is very marked, there appears to be a positive diminution of them in Delirium Tremens. A certain allowance must be made, however, for the abstinence from food, which will of itself occasion a reduction in the quantity excreted.

it appears that the quantity of these phosphates in the urine chiefly varies with the amount of them contained in the food, into many articles of which they enter largely (§§ 76, 78); but he has also ascertained that their formation within the system is determined by the presence of their bases; for if any earthy salt, a little chloride of calcium or sulphate of magnesia for instance, be taken into the system, the quantity of earthy phosphates in the urine undergoes an increase. The small quantity of carbonate of lime taken into the system with the food (§ 77), or set free by the slow disintegration of the osseous tissue, is probably excreted in Man almost entirely in the form of phosphate; although of the much larger amount ingested by herbivorous animals, a considerable proportion is excreted in the urine in its original state. The Earthy Phosphates, although insoluble in water, are soluble in all acid liquids; and they are held in solution in Urine, like the urates, by the acid phosphate of soda. Their precipitation in an alkaline state of the urine is owing to the want of this solvent, not to an excess in their production; for, as Dr. Bence Jones has pointed out, that excess of alkaline and earthy phosphates in the urine which constitutes the true 'phosphatic diathesis,' is generally coincident with a highly acid state of the urine.—The only other inorganic saline constituent of the Urine, whose quantity gives it importance is *Chloride of Sodium*. By far the larger proportion of this is doubtless derived directly from the food; but little being furnished by the disintegration of Muscle, which will set free potash rather than soda (§ 307). The amount eliminated by the urine is consequently subject to great variation, it being the function of the Kidneys to remove whatever is superfluous, so as to prevent the blood from becoming overcharged with this substance (§ 82). Of the chloride of sodium introduced as food, a part appears to undergo decomposition in the system, whereby hydrochloric acid is furnished to the gastric fluid, and soda to the bile; part of this acid, however, must reunite with its base in the alimentary canal, so that the chloride of sodium thus regenerated will be absorbed with the products of the digestive operation.—Although *Nitric Acid* cannot be regarded as a normal constituent of the Urine, yet the recent investigations of Dr. Bence Jones* show that it is formed by a combustive process within the body, whenever ammoniacal salts are introduced into the system; its amount, however, being very small. He has also found that it is generated after the ingestion of small quantities of urea; a fact which affords some confirmation to the doctrine of Frerichs (§ 637), that urea may undergo decomposition into carbonate of ammonia, whilst still circulating in the current of blood.—The presence of *Oxalic Acid* in the urine (in combination with Lime) has been usually regarded as a pathological phenomenon, consequent upon an irregular performance of the retrograde metamorphosis of the tissues; but there can be no doubt that it may also result from the presence of soluble salts of oxalic acid in certain articles of vegetable food.†

642. The ordinary *acid* reaction of the Urine appears to be due, not to the presence of any free acid, but to the conversion of the *basic* phosphate of soda into the *acid* phosphate, by the subtraction of a part of the base, which occurs when uric, hippuric, lactic, or other free acids come into

* "Philosophical Transactions," 1851.

† See Dr. Golding Bird on "Urinary Deposits," 3rd Edit., pp. 218—238.

contact with the former substance. There is no adequate reason to believe, that, in the healthy state, there is ever any other cause than this; although in morbid urine, free organic acids are almost certainly present.* It has been shown by the researches of Dr. Bence Jones, however, that the acid reaction is far from being constant in its degree, even when an ordinary mixed diet is steadily employed; for that it varies at different periods of the day, increasing and decreasing *inversely with the acidity of the stomach* (§ 443). Thus the acidity of the Urine decreases soon after taking food, whilst that of the Stomach is increasing; and attains its lowest limit from three to five hours after a meal, frequently giving place to an alkaline reaction. The acidity then gradually increases, whilst that of the stomach is decreasing; and attains its highest limit after a fast of some hours, when the stomach is quite empty, and its secretion neutral. If no food be taken, the acidity does not decrease, but remains at nearly the same point for ten or twelve hours. When *animal* food was alone employed, the diminution of the acidity after a meal was more marked, and continued longer, than when a mixed diet was eaten (apparently on account of the greater demand for acid in the stomach); and the acidity did not rise quite so high after fasting, as with a mixed diet. On the other hand, when the diet was purely *vegetable*, the diminution of its acidity was never such as to render the urine absolutely alkaline, although its acidity was reduced to the point of neutrality; and the increase of its acidity after fasting was sometimes very considerable, though by no means so marked as the decrease of alkalescence.—These diurnal variations in the acidity of the urine make it highly probable that corresponding variations occur in the alkalescence of the blood; such diurnal variations being produced by the quantity of acid separated from it, and poured into the stomach for the purpose of dissolving the food. The introduction of dilute sulphuric acid into the stomach, even in large doses, was not found to produce any decided change in the acidity of the urine; the only perceptible effect being a slight diminution of the decrease which takes place after taking food, and a slight augmentation of the increase after fasting. On the other hand, the use of liquor potassæ in large doses lessens the acidity of the urine, preventing it from rising after fasting to the height it would otherwise attain, and increasing its alkalescence after a meal; but it does not render the urine by any means constantly alkaline, nor does it hinder the variations produced by the state of the stomach from being very evident. Tartaric acid, in large doses, increases the acidity of the urine, causing it to rise considerably higher than usual after a fast, but not preventing that which is passed a few hours after food from becoming alkaline. Tartrate of potash in large doses, on the other hand, has a marked effect in rendering the urine alkalescent; still, it does not prevent the usual recurrence of the acidity some hours after a meal.†

643. It seems to have been clearly proved by Dr. Bence Jones (loc. cit.), that there is no relation whatever between the *acidity* of the urine and the *absolute amount* of Uric acid which it may contain; for in the urine which is most acid, and which deposits the largest uric-acid sedi-

* See Prof. Lehmann's "Lehrbuch der Physiologischen Chemie," band ii. pp. 398–400.

† See Dr. Bence Jones's 'Contributions to the Chemistry of the Urine,' in "Philosophical Transactions," 1849.

ment, very little uric acid may really exist; whilst that which contains most uric acid may hold it in perfect solution, and may have but a feeble acid reaction.*—The main cause of the deposit of Uric-acid sediments is doubtless the presence of some other acid; for the addition of any acid to healthy urine passed soon after food, is always sufficient to produce it. But the deposit takes place less readily if the temperature of the fluid be high, since the solvent power of the acid phosphate of soda is then more strongly exerted; so, on the other hand, a deposit often takes place in urine which would not otherwise exhibit it, through an unusual reduction in its temperature, as by exposure to the cold air of a sleeping-room in the winter. Again, the deposit of uric-acid sediment is favoured by concentration of the liquid, which thus augments the proportion of the urate to the water, and at the same time increases the acid reaction; and thus urine whose constituents are otherwise normal, may throw down a copious deposit of this kind, merely from deficiency of water; whilst an unusual amount of uric acid may be really present without being deposited,—the urine, too, possessing its ordinary acidity,—if the proportion of water be large. Thus the uric-acid sediment may be regarded as dependent upon three concurrent conditions;—(1) Decrease of temperature; (2) Increased proportion of uric-acid compound to the water, positively or relatively; (3) Increased acidity of the urine. Sometimes one condition is most influential, sometimes another; but they are all usually concerned in some degree.

644. The Urine of Herbivorous animals is almost invariably *alkaline;* partly because their food contains a large quantity of alkaline and earthy bases, in combination with citric, tartaric, oxalic, and other acids, which are decomposed within the system (§ 83); and partly because the amount of sulphuric and phosphoric acids, generated as products of the oxidation of the elements of the tissues or of the surplus-food, is not sufficient to neutralize them. Such is the condition which occasions the alkalinity of Human Urine, when a portion of the acid which would otherwise show a predominance, is directed into another channel; and it is exaggerated in those states, in which, either from the irritating nature of the food, or from the irritable condition of the stomach, an undue quantity of acid is poured-out into that viscus; so that, its reaction being habitually acid, that of the urine becomes habitually alkaline. Such a state of the urine must be carefully distinguished, as Dr. Bence Jones has pointed out,† from that in which the alkalescence is due to the presence of *volatile*, and not to that of *fixed* alkali; the difference being easily recognizable by the influence of the liquid upon reddened litmus-paper, for the restoration of its blue colour is permanent in the latter case, but only transitory in the former. The alkalescence due to the presence of volatile alkali is due to the decomposition of urea, whilst the urine is yet within the bladder, through the agency of morbid secretions of that viscus; and it disappears when this organ returns to its healthy

* It will be remembered that these sediments nearly always consist of Uric acid in union with a base (§ 56); this base is regarded by Prof. Lehmann as chiefly soda; whilst Dr. Bence Jones, in common with Dr. Golding Bird, maintains it to be ammonia. The term 'uric-acid sediment' is used above to designate this compound, whatever may be the substance with which the uric acid is united.

† "Medical Times," Dec. 13, 1851.

state. On the other hand, the alkalescence from fixed alkali proceeds from disordered action of the stomach, which is usually connected with disorder of the general system; and it persists until this can be remedied. In both forms of alkalescence, there is a precipitation of earthy phosphates; but in the alkalescence from fixed alkali, the precipitate usually consists almost entirely of phosphate of lime; whilst in that from volatile alkali, the amorphous sediment of phosphate of lime is mingled with prismatic crystals of the phosphate of ammonia and magnesia. These precipitates may be obtained from healthy urine, by adding to it a solution of potash or of ammonia; and the decomposition of such urine, which begins to take place very soon after it leaves the body, gives rise to the same precipitation, by the production of carbonate of ammonia at the expense of its urea (§ 52).

645. Thus, then, we have seen that the Kidneys serve as the special instruments for depurating the Blood of those highly-azotized compounds, which are formed in the system by the decomposition of the materials of the albuminous and gelatinous tissues, and also by that of the non-assimilated components of the food. We have seen, also, that they serve for the removal of certain compounds of which carbon is a principal ingredient; and these, although normally present in but small amount, may undergo a marked increase in disease, especially when the liver is insufficiently performing its functions, or the respiratory process is obstructed. Further, we have been led to regard the Kidneys as the emunctory, not only for the superfluous water of the blood, but also for those saline compounds, which, having been introduced into the system, or generated within it, in larger amount than is compatible with the normal constitution of the blood, or than is required for the reparation of the solids of the body, or for the production of its fluid secretions, are only fitted for elimination. And this statement is to be extended from saline compounds, to such other soluble matters as are not removed by other channels. On this point a very elaborate series of researches was made by Wöhler,* who showed that of the soluble salts taken into the circulation, those are most readily excreted which produce a determination of blood towards the kidneys, whereby an increased quantity of liquid is filtered-off through the outlet which they afford. And it is in this manner that the system makes an effort to free itself (so to speak) from various foreign substances which have been introduced into it by absorption, and which would be injurious if retained; the rate at which it does so being in a great degree dependent upon the functional activity of the Kidneys (§§ 89, 207, 208).—It does not appear, however, that the excretion of the organic compounds which are formed within the system, is augmented by those 'diuretic' medicines, which, by determining an increased flow of blood to the Kidneys, cause a larger amount of liquid to be passed off through them. On the contrary, it would seem as if, by producing congestion and irritation, they sometimes interfered with the normal process of secretion; so that the quantity of solid constituents is actually decreased, notwithstanding the large augmentation in the watery part of the urine. This very important fact has been demonstrated by Prof. Krahmer,† who gives the following as the result of his observations

* "Müller's Elements of Physiology," translated by Baly, p. 589.
† "Heller's Archiv.," Dec., 1847.

upon the amounts excreted in 24 hours, after the administration of diuretics to persons in health :—

| *Medicine given.* | *Total Solids in Urine.* | *Organic Compounds.* | *Inorganic Compounds.* |
|---|---|---|---|
| None | 2·40 oz. | 1·28 oz. | 1·13 oz. |
| Juniper | 2·12 „ | 0·94 „ | 1·18 „ |
| Venice Turpentine | 1·94 „ | 1·11 „ | 0·83 „ |
| Squill | 2·25 „ | 1·04 „ | 1·21 „ |
| Digitalis | 2·45 „ | 1·28 „ | 1·17 „ |
| Guiacum | 2·43 „ | 1·38 „ | 1·05 „ |
| Colchicum | 2·32 „ | 1·36 „ | 0·96 „ |

Similar results have been obtained by Dr. Golding Bird;* who has shown that, on the other hand, there is a class of remedies, which is capable of producing the most marked increase in the amount of organic as well as of saline matters eliminated by the Kidneys. These are the Alkalies and their carbonates, with such of their salts as are formed by acids which are decomposed in the blood into the carbonic, such as the acetates, tartrates, and citrates. It has been shown (CHAP. II., Sect. I.) that the alkalies and their carbonates have a powerful solvent action on the albuminous compounds generally; and that they tend to break up these compounds into simpler forms of combination. Hence it seems likely that their presence in the Blood in increased amount, will tend to hasten the retrograde metamorphosis of the tissues; their chemical force being exerted, not merely upon those which are already in a state of disintegration, but also upon those, which, being disposed to degenerate, cannot exercise that resisting power, which they possess when in a state of complete vital activity (§ 116). The increase which their administration occasions in the solids of the Urine, is strikingly displayed in the following comparative table, given by Dr. G. Bird, of the entire constituents of the secretion passed during 24 hours, before and after the administration of three drachms of acetate of potash :—

| | *Before Medicine.* | *After Medicine.* |
|---|---|---|
| Quantity of Urine | fl ℥xvi. | fl ℥xlvi. |
| Specific Gravity | 1·025 | 1·017 |
| Total Solids | 416 grs. | 782 grs. |
| Uric Acid | 2·6 grs. | 3·5 |
| Urea | 130·5 „ | 202·4 |
| Other Organic Compounds | 189·3 „ | 295·5 |
| Soluble Salts | 72·0 „ | 248·4 |
| Insoluble Salts | 21·6 „ | 32·2 |

The increase (176·4 grains) in the quantity of 'soluble salts,' is to be chiefly set down to the account of the medicine taken-in; but the whole remainder of the augmentation seems fairly attributable to the increased metamorphosis. A certain degree of such increase is producible by the simple ingestion of a large amount of water; so that this is by no means so inoperative as it might at first sight appear, in cleansing and purifying (so to speak) the penetralia of the system.—It seems highly probable that the 'critical evacuations' of urine, as of sweat, or fæcal matter, on

* "See his 'Lectures on the Influence of Researches in Organic Chemistry on Therapeutics,' in "Medical Gazette," 1848, vol. xlii. p. 230.

which the older physicians were accustomed to lay great stress, are really charged with noxious substances, of which the blood is thus depurated; and that great benefit would frequently arise in practice from the use of the 'alterative diuretics,' as suggested by Dr. G. Bird, where (as in chronic rheumatism, gout, &c.,) there is reason to believe that a quantity of mal-assimilated matter exists in the system, of which it is important to get rid. In many such cases, indeed, clinical observation had already established the benefit derivable from such medicines, without affording the rationale of it.

### 4.—*Of the Skin;—Cutaneous Transpiration.*

646. The Skin is the seat of various secretions, for each of which it is provided with special organs (§§ 237, 238); but these have reference chiefly to its own protection, or to some other *local* purpose; and the only one which can be regarded as truly *excrementitious*, is the Transpiration of aqueous fluid, holding certain matters in solution. The elimination of this fluid from the blood is effected by the *Sudoriparous* glandulæ (Fig. 125), which are seated rather *beneath* than *in* the Cutis, and are diffused in varying proportions over the entire surface of the body (§ 238). According to Mr. Erasmus Wilson,* as many as 3528 of these glandulæ exist in a square inch of surface on the palm of the hand; and as every tube, when straightened out, is about a quarter of an inch in length, it follows that, in a square inch of skin from the palm of the hand, there exists a length of tube equal to 882 inches, or 73½ feet. The number of glandulæ in other parts of the skin, is sometimes greater, but generally less than this; and, according to Mr. Wilson, about 2800 may be taken as the average number of pores in each square inch throughout the body. Now the number of square inches of surface, in a man of ordinary stature, is about 2500; the total number of pores, therefore, may be about *seven millions*; and the length of the perspiratory tubing would thus be 1,750,000 inches, or 145,833 feet, or 48,611 yards, or nearly 28 miles.—

FIG. 125.


Sudoriparous Gland from the palm of the hand, magnified 40 diam.;—*a*, *a*, contorted tubes, composing the gland, and uniting into two excretory ducts, *b*, *b*, which unite into one spiral canal that perforates the epidermis at *c*, and opens on its surface at *d*; the gland is imbedded in fat-vesicles, which are seen at *e e*.

* "On the Management of the Skin," 3rd edit. p. 37.

Although a separation of fluid by this extensive glandular apparatus is continually taking place, yet this fluid, being usually carried-off in the form of vapour as fast as it is separated, does not accumulate so as to become sensible. If, however, from the increased amount of the secretion, or from the condition of the surrounding air, the whole fluid thus poured out should not evaporate, it accumulates in minute drops upon the surface of the skin. Thus the Sudoriparous excretion may take the form either of *sensible* or of *insensible* transpiration; the latter being constant, the former occasional. It is difficult to obtain enough of this secretion for analysis, free from the sebaceous and other matters which accumulate on the surface of the skin; and its character can only, therefore, be stated approximately. It has usually an acid reaction, which seems due to the presence of acetic acid; and to this, or to lactic acid, we are probably to attribute the sour smell which it has, especially in some disordered states of the system. The proportion of solid matter, according to Anselmino, varies between 5 and 12·5 parts in 1000. The greater part of it consists of organic matter, the larger proportion of which appears to be a protein-compound in a state of incipient decomposition; urea, however, has been detected in this product by Dr. Landerer.* The remainder consists of saline compounds; of which the chlorides of potassium and sodium appear to be pretty constantly present; whilst muriate of ammonia, alkaline phosphates, free acetic and butyric acids, and acetate of soda, have also been said to occur in it.—The proportion of solid ingredients would probably be found larger in the true secretion of the Sudoriparous glands, if we had the means of collecting it separately; for of the whole fluid which passes off from the surface of the skin, only a portion can be properly said to be *secreted* by these glands, a large part, as in the case of the Kidneys, being the product of simple *transudation* (§ 636). It will be this part which will undergo augmentation, when a special determination of blood to the skin is produced by external heat; and there is no more reason to think that an increase in the amount of *solid* matter thus excreted is induced by such agency, than that an increase in the solids of the urine can be determined by ordinary diuretics (§ 645). Hence the debilitating effects commonly assigned to profuse perspirations, must be attributed to some other causes; and these it does not seem very difficult to find. Thus, the great fatigue which is experienced as a consequence of muscular exertion in a heated atmosphere, may fairly be set down to the diminished activity of the respiratory process at high temperatures (§ 564, *a*); and the 'colliquative sweating' of hectic fever is obviously not a cause, but a consequence, of the debilitated state of the general system.

647. The entire amount of fluid which is 'insensibly' lost from the Cutaneous and Pulmonary surfaces, is estimated by Seguin at 18 grains per minute; of which 11 grains pass off by the skin, and 7 by the lungs. The maximum loss by Exhalation, cutaneous and pulmonary, during twenty-four hours, (except under very peculiar circumstances,) is 5 lbs; the minimum $1\frac{2}{3}$ lb. It varies greatly, according to the condition of the atmosphere, and that of the body itself; and these variations, as we shall hereafter see (§ 665), have a most important share in the regulation of the temperature of the body. The whole amount of Cutaneous transpiration,

* "Heller's Archiv.," band iv. p. 196.

'sensible' and 'insensible,' is greatly increased by heat and dryness of the surrounding air; for the heat occasions the determination of an augmented amount of blood to the cutaneous vessels; and of the fluid which thus transudes, a large portion is carried-off in the state of vapour. The more the heated atmosphere is already charged with watery vapour, the smaller will be the proportion of the transuded fluid that will thus 'insensibly' pass away; and the more will accumulate as 'sensible' perspiration. Exact observations on this point, however, are much wanting, in which not merely the temperature, but the hygrometrical state of the air should be precisely determined; the best hitherto recorded being those made by Dr. Southwood Smith* at the Phœnix Gas Works, in which the former element only was carefully noted. These observations were made upon eight of the workmen employed in drawing and charging the retorts and in making up the fires, during which they are exposed to intense heat; the men were accurately weighed in their clothes, immediately before they began, and after they had finished their work; and in the interval between the first and second weighings, they were not allowed to partake of any solid or liquid *ingesta*, nor to part with urine or fæces.

Experiment I. Nov. 18, 1836. Day bright and clear. Temperature of the air in which the men worked, 60° Fahr. Barometer 29·25 in. to 29·4 in. Duration of labour, 45 minutes.—Average loss of weight, 3 lbs., 6 oz.; maximum, 4 lbs. 3 oz.; minimum 2 lbs. 8 oz.

Experiment II. Nov. 25, 1836. Day foggy, with scarcely any wind. Temperature of the air, 39° Fahr. Barometer 29·8. Duration of labour, 75 minutes.—Average loss of weight, 2 lbs. 2 oz.; maximum, 2 lbs. 15 oz.; minimum, 14 oz.

Experiment III. June 3, 1837. Day exceedingly bright and clear with little wind. Temperature of the air, 60°. Duration of labour, 60 minutes.—Average loss of weight, 2 lbs. 8 oz.; maximum, 3 lbs.; minimum, 2 lbs.

Experiment IV. On the same day, two other men worked in an unusually hot place for 70 minutes; the loss of weight of one of these was 4 lbs. 14 oz.; and of the other 5 lbs. 2 oz.

Although the individuals subjected to these experiments were not in all instances the same, yet there was enough of identity among them, to admit of the certain inference, that the amount of fluid lost must be influenced by the state of the individual system, as well as by that of the surrounding medium. Thus in the second experiment, Michael Griffiths lost 2 lbs. 6 oz., and Charles Cahell 2 lbs. 15 oz.; whilst in the third, Michael Griffiths lost 3 lbs., and Charles Cahell only 2 lbs. It is probable that the amount of liquid ingested not long previously, might have a considerable influence on the quantity lost by transpiration under such circumstances.

648. The Cutaneous excretion, as already pointed-out, is in great degree vicarious with the Urinary, in regard to the amount of fluid eliminated; the urine being more watery in proportion as the cutaneous exhalation is diminished in amount, and *vice versâ* (§ 636). But we are also to look at these two excretions as vicarious, in regard to the elimination of the products of the 'waste' of the system. The share which the Skin has in

* "Philosophy of Health," vol. ii. pp. 391–396.

this office has probably been generally under-rated. There is reason to believe that at least 100 grains of azotized matter are excreted from it daily; and any cause which checks this excretion, must throw additional labour on the kidneys, and will be likely to produce disorder of their function.—The secreting action of the Skin is influenced by general conditions of the vascular and nervous systems; which are as yet ill understood. It is quite certain, however, that through the influence of the latter the secretion may be excited or suspended; this is seen on the one hand in the state of syncope, and in the effects of depressing emotions, especially fear, and its more aggravated condition, terror; and on the other, in the dry condition of the skin during states of high nervous excitement. It is very probable that, in many forms of fever, the suppression of the perspiration is a cause, rather than an effect, of disordered vascular action; for there are several morbid conditions of large parts of the surface, in which the suppression of the transpiration appears to be one of the chief sources of danger, having a tendency to produce congestion and inflammation of internal organs. From the experiments of Dr. Fourcault, it appears that complete suppression of the perspiration in animals, by means of a varnish applied over the skin, gives rise to a state termed by him 'cutaneous asphyxia;' which is marked by imperfect arterialization of the blood, and considerable fall of temperature, (§ 660); and which, as it produces death in the lower animals, would probably do the same in Man. A partial suppression by the same means gives rise to febrile symptoms, and to albuminuria.—There can be no doubt whatever, that imperfect action of the Cutaneous glandulæ, consequent upon inactive habits of life and want of ablution, is a very frequent source of disorder of the general system; occasioning the accumulation of that decomposing organic matter in the blood, which it is the special office of these glandulæ to eliminate. Hence the due maintenance of health requires that this excretion should be promoted by the use of the natural and appropriate means just referred-to; and this is the more necessary, when from any cause the function of the kidneys is imperfectly performed. There are many diseased states, moreover, in which there appears to be a special determination of the *materies morbi* to the skin; and in which, therefore, the use of means that promote the cutaneous excretion constitutes the most efficient method of eliminating them from the blood.*

* The practical value of active diaphoresis in many febrile diseases, is well understood by the native practitioners among the Negroes of the Guinea Coast; who, according to Dr. Daniell ("Medical Topography and Native Diseases of the Gulf of Guinea," pp. 119-20) make use of it most successfully in the treatment of adynamic remittent fevers. Dr. Daniell states that having himself had abundant experience of its efficacy, he has no doubt of its superiority in these cases to the ordinary practice of venesection, saline purgatives, large doses of calomel, &c. And he has repeatedly stated that one great secret of preserving health in tropical climates, lies in due attention to the cutaneous functions.

# CHAPTER XIII.

## EVOLUTION OF HEAT, LIGHT, AND ELECTRICITY.

### 1.—*General Considerations.*

649. The series of Nutritive operations which has now been passed in review, has been shown to consist in the continual appropriation, by the animal organism, of certain 'organic compounds' or 'alimentary materials,' which have been generated for its use by Plants; and in the constant restoration of their elements to the Inorganic world, either in the very same forms of combination in which they originally existed there, or as products of incipient decay, by whose further decomposition those simple binary compounds will be reproduced. And thus, so far as the material components of the Organic Creation are concerned, the agency of Vegetable life is concerned in withdrawing them from the Mineral world, and that of Animal life in returning them to it, after they have served their purpose in the living structure. But if we examine into the source of those active powers or 'forces,' on whose operation every change, no less in the organized body than in what is commonly designated as 'inert' matter, is dependent, we shall find that they are all traceable to the solar radiations. It is by the action of the Light and Heat of the Sun upon the Vegetable germ, that it is enabled to exercise its wonderful transforming capacity, whereby it extracts carbon, hydrogen, nitrogen, and oxygen, from the carbonic acid, water, and ammonia furnished by the atmosphere or the soil; and that it converts these into the albuminous, saccharine, and oleaginous compounds, which are the destined food of Animals. And it is under the influence of Heat chiefly derived from the same source, that the greater number of tribes of Animals are enabled to apply these compounds to the purposes of organization; and that, through the peculiar instruments thus constructed, those various kinds of *Vital force* are evolved, whose operations are so different from any which we witness in the Inorganic world. Accordingly we observe that the 'rate of life' in this larger proportion of the Animal kingdom, is regulated, as in Plants, by the amount of Heat supplied to the organism from external sources; and that, when the external temperature is reduced below a certain point, there is an entire cessation of all vital activity.* But there are certain tribes, especially Birds and Mammals, which possess the power of generating *Heat* within themselves, to such a degree as to render the rate of their vital processes almost entirely independent of external influences; and there is probably no one species that can exercise this power more effectually, and through a greater range of external conditions, than Man is able to do. Of this we shall presently have evidence.—The evolution of *Light*, again, is by no means an unusual phenomenon among the lower tribes of Animals; but where it does occur, it usually appears to have some special purpose, as is obvious enough in the

* See "Princ. of Phys., Gen. and Comp." CHAP. III. Sect. 3.

case of the glow-worm and other luminous Insects. But the luminosity which is occasionally exhibited in Man, must be regarded as an altogether abnormal phenomenon, whose physiological interest arises out of the peculiarity of the circumstances under which it presents itself.—Of the degree in which *Electricity* is generated in the living body, we know comparatively little. There is strong evidence that a disturbance of Electric polarity must take place in every action of Organic as well as of Inorganic Chemistry; and thus that every molecular change in the Animal as well as in the Vegetable organism must involve an alteration in its electric condition. But it would seem that in the Animal body generally, these alterations are made to balance each other so exactly, that no considerable disturbance of the electric equilibrium ordinarily takes place in the organism as a whole; and it is only in certain peculiar cases (as in the Electric Fishes) that a provision exists for the generation of Electricity in considerable amount and intensity, with a view to some special purpose. In the Human subject, however, an extraordinary production of free Electricity, as of Light, occasionally presents itself; and this, taken in connection with other evidence, would seem rather to indicate a departure from the usual balance between the opposite electrical changes continually taking place, than to be due to the introduction of any extraordinary sources of electric disturbance.*

## 2.—*Evolution of Heat.*

650. All the vital actions of the body of Man, as of that of 'warm-blooded' animals generally, require an elevated temperature as a condition of their performance; and the high degree of constancy and regularity which is observable in these actions, appears to depend in great degree upon the provision which the organism contains within itself, for the maintenance of that temperature at a fixed standard. This constancy and regularity are most remarkably exhibited in the various *periodical* changes to which the body is subject both in health and disease; the uniformity of whose recurrence is due to a corresponding uniformity in the rate of vital action taking place in the interval. Thus, as will be shown hereafter, the period of parturition is in great degree determined by the maturation of the fœtal structures; and the uniformity of the time which this requires (like the corresponding uniformity in the period of development in the embryo bird) may be fairly attributed to the regularity of the supply of Heat, which is the power that especially determines the formative operations. For the periods of all similar phenomena in 'cold-blooded' animals, which have no power of maintaining an independent temperature, exhibit no such uniformity; being entirely dependent (as in Plants) upon the degree of *external* warmth to which their bodies are subjected.—We shall now inquire, in the first place, into the amount of Heat thus generated by Man; and then into the sources of its production.

* Having recently had an opportunity of witnessing some of the experiments made by M. Du Bois Reymond with a magneto-electrometer of extraordinary sensitiveness, the Author can bear his personal testimony to the fact, that the electricity even of the corresponding fingers of the two hands is very seldom equally balanced, and that the existence of even the slightest scratch or abrasion of surface upon one of them produces a very marked disturbance.

651. Our present knowledge of the ordinary Temperature of the Human body under different circumstances, is chiefly due to the investigations of Dr. J. Davy.*—The first series of his observations included 114 individuals of both sexes, of different ages, and among various races, in different latitudes, and under various temperatures; the external temperature, however, was in no instance very low, and the variations were by no means extreme. The mean of the ages of all the individuals was 27 years. The following is a general statement of the results, the temperature of the body having been ascertained by a thermometer placed under the tongue:—

| | | | |
|---|---|---|---|
| Temperature of the air | 60° | Average temperature of the body | 98·28° |
| " " | 69° | " " " | 98·15° |
| " " | 78° | " " " | 98·85° |
| " " | 79·5° | " " " | 99·21° |
| " " | 80° | " " " | 99·67° |
| " " | 82° | " " " | 99·9° |
| Mean of all the experiments | 74° | Mean of all the experiments | 100° |
| Highest temperature of air | 82° | Highest temperature of body | 102° |
| Lowest temperature of air | 60° | Lowest temperature of body | 96·5° |

From this we see that the variations noted by Dr. Davy, which were evidently in part the consequence of variations in external temperature, but which were also partly attributable to individual peculiarities, amounted to 5½ degrees; the lower extreme might be found to undergo still further depression, if the inquiries were carried on in very cold climates.—Dr. Davy's subsequent inquiries have been directed to the determination of the various influences which tend to produce a departure from the average; and it will be advantageous to present his results in a systematized form, in combination with those of other observers. The most important of these variations seem to be those dependent upon Age, Period of the day, Exercise or Repose, Ingestion of Food or Drink, and External Temperature.

*a.* The temperature of *Infants*, according to the observations of Dr. Davy, M. Roger† and of Dr. G. C. Holland,‡ is somewhat higher than that of adults,§ provided that they are placed in conditions favourable to its sustenance; but, as will be shown hereafter, infants and young children are very inferior to adults in their power of resisting the depressing influence of external cold (§ 664). Their temperature, when examined immediately after birth by a thermometer in the axilla, is nearly 100°; but it quickly falls to about 95·5°, and gradually rises in the course of the next twenty-four hours to about 97·7° in weakly subjects, and to 99·5° in strong infants. Between four months and six years of age, M. Roger found the average temperature to be 98·9°; and between six and fourteen years of age, 99·16°.—The temperature of *aged* persons, from the obser-

* See his successive Memoirs in the "Philosophical Transactions," for 1814 (republished in Dr. D.'s "Anatomical and Physiological Researches"), 1844, 1845, and 1850.

† "Archiv. Gén. de Méd.," 1844.

‡ "Inquiry into the Laws of Life," 1829.

§ Dr. W. F. Edwards ("On the Influence of Physical Agents on Life," p. 115) gives as the result of his observations, which were only ten in number, that the temperature of infants is lower than that stated above; but it is obvious that these observations were made during the period of depression which occurs in the first days, whilst the respiratory function is becoming established.

vations of Dr. J. Davy, does not seem to be below that of persons in the vigour of life, provided that there be no external depressing influences; but they seem, like infants and young children, to have less power of resisting external cold, the temperature of their bodies being more easily and considerably reduced by it than is that of adults; and hence probably it has happened, that popular opinion assigns to them an habitually inferior temperature.

*b.* A slight *diurnal* variation in the temperature of the body appears usually to take place, quite irrespectively of external heat or cold; but this does not seem to be very constant either in its period or its degree, and is seldom very considerable. Thus Dr. Davy found from a long series of observations carried-on upon himself whilst in England, that the body was warmest in the morning, and coldest at night; whilst the reverse was the case in Barbadoes. The following table gives his average results:—

| | *Mean temperature under the tongue.* | | | *Temperature of Room.* | | |
|---|---|---|---|---|---|---|
| England | 7–8 A.M. 98·74° | 2–4 P.M. 98·52° | 12 P.M. 97·92° | 7–8 A.M. 50·9° | 2–4 P.M. 54·7° | 12 P.M. 62° |
| Barbadoes | 6–7 A.M. 98·07° | 12–2 P.M. 98·9° | 9–11 P.M. 99° | 6–7 A.M. 76·7° | 12–2 P.M. 83·6° | 9–11 P.M. 79° |

From the observations of M. Chossat on Birds, in which the diurnal variation amounts to $1\frac{1}{2}°$ Fahr., it seems that the maximum is pretty constantly at noon, and the minimum near midnight; and this corresponds well with what has already been pointed out, with regard to the relative activity of respiration at different periods of the twenty-four hours (§ 564, *i*). Probably there is a less capacity for generating heat during the night; so that, if the body be insufficiently protected by clothing, or be exposed to a low degree of external temperature, its own temperature will be more readily lowered: and thus the minimum of the whole day may come to present itself at this part of it, in a temperate climate; whilst in a tropical climate, the light bed-covering and free circulation of air usual in the sleeping-room, together with the depressing influence of repose, would tend to render the early-morning temperature the lowest.

*c.* That an increase in the heat of the body is produced by *exercise*, and that repose tends to its reduction, is a matter of familiar experience; but the observations of Dr. Davy show that there is scarcely any perceptible difference in the heat of the deep-seated parts, the augmentation and depression being confined to the extremities. Thus, on one occasion recorded by him, the temperature of the air of the room before walking being 60°, that of the feet (the thermometer being placed between the toes) being only 66°, that of the thermometer under the tongue being 98°, and that of the urine 100°,—the temperature after a walk in the open air at 40°, the exercise having diffused a feeling of gentle warmth through the body, was 96·5° in the feet, 97° in the hands, 98° under the tongue, and 101° in the urine. So on another occasion, the temperature having been 66° in the room, 75° in the feet, 81° in the hands, 98° under the tongue, and 100° in the urine,—after a walk in air at 50°,

e temperature was 99° in the feet, 98° in the hands, 98° under the ngue, and 101·5° in the urine.

*d.* The influence of *ingestion of food* upon the temperature of the body s not yet been duly investigated. Common experience leads to the conusion, that after a meal, as after exercise, there is a greater warmth the extremities; but Dr. Davy's observations show that, in his own se, whilst in England, there was usually an appreciable depression imediately after dinner, though in Barbadoes the effect of a moderate eal was to produce an elevation. In both cases, however, Dr. D. obrved that the ingestion of *wine* has a positively depressing influence on ie temperature of the body, which increases with the quantity taken; id it may have been the constant employment of wine with his dinner, hich was the real cause of the depression observed in England.*

*e.* The influence of *external temperature* is sufficiently apparent in the bservations already cited; for although external cold may act in a ifferent degree on different individuals, according to their respective ges, powers of resistance, &c., yet there is ample proof that on the hole a continued exposure to it reduces the temperature of the body omewhat below its ordinary standard, whilst continued exposure to heat ccasions a slight elevation in the temperature of the body. The inuence of cold is, of course, most powerfully exerted when the body is at est; and under such circumstances Dr. Davy found the temperature of is own body to be reduced, on an average of four observations, to 96·7°, he average temperature of the surrounding air having been 37°. On omparing the bodily temperature of different individuals working in ooms of various temperatures in the same factory, Dr. Davy found the ongue-thermometer rise to 100° in one man, and to 100·5° in another, who had been working for some hours in a room at 92°; whilst it was 99° in a young woman who worked in a room at 73°, and only 97·5° in another who worked in a temperature of 60°. The effects of seasonal change are less marked in Man, than they are in the lower animals, which are more exposed to extremes of temperature; but it seems principally exerted in modifying the heat-producing power. For it has been shown by Dr. W. F. Edwards (Op. cit.), that warm-blooded animals are more speedily killed by extreme cold in summer than in winter; and it seems probable, therefore, that we are partly to attribute the peculiar chilling influence of a cold day in summer, and the oppressiveness of a warm day in winter, to the seasonal change in the body itself; although the effect is doubtless referable in part to the effect of contrast upon our own feelings.

652. The usual Temperature of the body occasionally undergoes considerable alteration in *disease;* and this in the way either of increase or

* This difference in effect noted by Dr. Davy, between a moderate quantity of wine taken with dinner in England and in Barbadoes, seems readily explicable by the fact that the presence of Alcohol in the blood diminishes for a time the energy of the proper combustive process (§ 264, *h*). For when the temperature of the atmosphere is considerably below that of the body, this retardation of the combustive process occasioned by the wine will allow the heat of the body to be lowered by it, notwithstanding the tendency to increased activity of the circulation and respiration which the meal alone would exert. In a warm climate, on the other hand, the cooling influence of the external air would not be sufficient to produce this reduction in the temperature of the body, notwithstanding the retarding influence of the wine upon the combustive process.

of diminution. Thus in maladies which involve an acceleration of pulse and a quickening of the respiration, the temperature is generally higher than usual, even though a large portion of the lung may be unfit for its function. This is often remarkably seen in the last stages of phthisis, when the inspirations are extremely rapid, and the pulse so quick as scarcely to admit of being counted; the skin, in such cases, often becomes almost painfully hot. On the other hand, in diseases of the contrary character, such as 'morbus cœruleus,' asthma, and cholera, the temperature of the body falls; a reduction to 78° having been noticed in the former maladies, and to 67° in the latter. The range observed by M. Andral in diseases which less affected the calorifying function, was from 95° to 107·6°; and by M. Roger (loc. cit.), in diseases of children, from 74·3 to 108·5. Prof. Dunglison* speaks of having seen the thermometer at 106° in scarlatina and typhus; and Dr. Francis Home,† found it to stand at 104° in two individuals in the cold stage of an intermittent, whilst it afterwards fell to 101°, and subsequently to 99°, during the sweating stage. Dr. Edwards mentions a case of tetanus, in which the temperature of the body rose to 110¾°. The following observations have been made on this subject by M. Donné:‡ in a case of puerperal fever, the pulse being 168, and the respiration 48 per minute, the temperature was 104°; in a case of hypertrophy of the heart, the pulse being 150 and the respirations 34, the temperature was 103°; in a case of typhoid fever, the pulse being 136, and the respirations 50, the temperature was 104°; and in a case of phthisis, the pulse being 140, and the respirations 62, the temperature was 102°; on the other hand, in a case of jaundice, in which the pulse was but 52, the temperature was only 96·40°; but the same temperature was observed in a case of diabetes, in which the pulse was 84. These limited observations, whilst they clearly indicate that a *general* relation exists between the temperature of the body and the rapidity of the pulse, also show that this relation is by no means invariable, but that it is liable to be affected by several causes, of which our knowledge is as yet very limited.—It is not a little remarkable that the temperature of the body should sometimes rise considerably after death; and this not merely in such diseases as Cholera, in which it has undergone an extreme depression during the latter part of life; but even in the case of febrile disorders, in which the temperature during life has been above the usual standard. This has been ascertained by Dr. Bennett Dowler§ of New Orleans, on the bodies of those yellow-fever subjects which have already been referred-to as exhibiting a remarkable degree of *molecular* life after *somatic* death (§§ 328, 522). In one case, for example, the highest temperature during life was in the axilla, 104°; ten minutes after death it had risen to 109° in the axilla; fifteen minutes afterwards it was 113° in an incision in the thigh; in twenty minutes the liver gave 112°; in one hour and forty minutes, the heart gave 109°, and the thigh in the former incision 109°; and in three hours after the

* "Human Physiology," 7th edit., vol. ii. p. 225.
† "Medical Facts and Experiments," London, 1759.
‡ "Archives Gén. de Méd.," Oct. 1835; and "Brit. and For. Med. Rev." vol. ii. p. 248.
§ "Western Journal of Medicine and Surgery," June and Oct., 1844; cited in "Philadelphia Medical Examiner," June, 1845, and in Prof. Dunglison's "Human Physiology," 7th edit., vol. ii. p. 718.

[re]moval of all the viscera, a new incision in the thigh gave 110°. It is [c]urious that the maximum of the heat observed after death should have [b]een in the thigh, and the minimum in the brain; as is shown in the [fo]llowing table of the highest amount of temperature noted in eight [d]ifferent regions in five subjects:—

| | *Thigh.* | *Epigastrium.* | *Axilla.* | *Chest.* | *Heart.* | *Brain.* | *Rectum.* | *Liver.* |
|---|---|---|---|---|---|---|---|---|
| | 113° | 111° | 109° | 107° | 109° | 102° | 111° | 112° |
| | 109° | 110° | 109° | 106·5° | 106° | 101° | 109° | 109° |
| | 109° | 109° | 108° | 106° | 105° | 101° | 107° | 108° |
| | 109° | 109° | 108° | 106° | 104° | 100° | 107° | 107° |
| | 108° | 109° | 107° | 105° | 104° | 99° | 106° | 106° |
| Mean | 109·6° | 109·6° | 108·2° | 106·1° | 105·6° | 100·6° | 108° | 108·4° |

653. Although there appears to be, for all species of animals, a distinct limit to the variations of bodily temperature, under which their vital operations can be carried on, this limitation does not prevent animals from existing in the midst of great diversities of external conditions; since they have within themselves the power of compensating for these, in a very extraordinary degree. This power seems to exist in Man to a higher amount than in most other animals; since he can not only support but enjoy life, under extremes, of which either would be fatal to many. In many parts of the tropical zone, the thermometer rises every day, through a large portion of the year, to 110°; and in British India it is said to be seen occasionally at 130°. On the other hand, the degree of cold frequently sustained by Arctic voyagers, and quite endurable under proper precautions, appears much more astonishing; by Captain Parry, the thermometer has been seen as low as —55°, or 87° below the freezing point; by Captain Franklin at —58°, or 90° below the freezing point; and by Captain Back at —70°, or 102° below the freezing point. In both cases, the effect of the atmospheric temperature on the body is greatly influenced by the condition of the air as to motion or rest; thus, every one has heard of the almost unbearable oppressiveness of the 'sirocco' or hot wind of Sicily and Italy, the actual temperature of which is not higher than has often been experienced without any great discomfort, when the air is calm: and, on the other side, it may be mentioned that, in the experience of many Arctic voyagers, a temperature of —50° may be sustained, when the air is perfectly still, with less inconvenience than is caused by air in motion at a temperature fifty degrees higher.* This is quite conformable to what might be anticipated on physical principles.

654. Again, the degree of moisture contained in a heated atmosphere, makes a great difference in the degree of elevation of temperature, which

* The Author has been informed by Sir John Richardson, that in his last Arctic Expedition, whilst at winter quarters, he was accustomed to go from his sitting-room, to the magnetic observatory at a short distance (about an ordinary street's breadth), without feeling it necessary even to put on a great-coat; although the temperature of the former was about 50°, and that of the air through which he had to pass to the latter was —50°, the difference being 100°. This immunity from chilling influence was chiefly attributable to the *dryness* and *stillness* of the atmosphere; but it is worthy of note that Sir J. R. and the whole of his party on this expedition, abstained entirely from alcoholic liquors; and the Author has received his personal assurance, that his experience on this occasion fully bore out his previous conviction, that continued severe cold is *much better* borne without recourse to these liquors, than under the employment of them.

may be sustained without inconvenience. Many instances are on record, of a heat of from 250° to 280° being endured in dry air for a considerable length of time, even by persons unaccustomed to a particularly high temperature; and persons whose occupations are such as to require it, can sustain a much higher degree of heat, though not perhaps for any long period. The workmen of the late Sir F. Chantrey were accustomed to enter a furnace in which his moulds were dried, whilst the floor was red-hot, and a thermometer in the air stood at 350°; and Chabert the "Fire-king," was in the habit of entering an oven whose temperature was from 400° to 600°.* It is possible that these feats might be easily matched by many workmen who are habitually exposed to high temperatures; such as those employed in Iron-foundries, Glass-houses, and Gas-works. In all these instances, the dryness of the air facilitates the rapidity of the vaporization of the fluid, whose secretion by the Cutaneous glandulæ is promoted by heat applied to the surface; and the large amount of caloric which is consumed in this change, is for the most part withdrawn from the body, the temperature of which is thus kept down. Exposure to a very elevated temperature, however, if continued for a sufficient length of time, does produce a certain elevation of that of the body; as might be expected from the statements already made, in regard to the variation in the heat of the body with changes in atmospheric temperature (§ 651). In the experiments of MM. Berger and Delaroche,† it was found that, after the body had been exposed to air of 120° during 17 minutes, a thermometer placed in the mouth rose nearly 7° above the ordinary temperature; it may be remarked, however, that as the body was immersed in a close box, from which the head projected (in order to avoid the direct influence of the heated air on the temperature of the mouth), the air had probably become charged with the vapour exhaled from the surface, and had therefore somewhat of the effects of a moist atmosphere. At any rate, the temperature of the body does not appear to rise, under any circumstances, to a degree very much greater than this. In one of the experiments of Drs. Fordyce and Blagden,‡ the temperature of a Dog, that had been shut up for half-an-hour in a chamber of which the temperature was between 220° and 236°, was found to have risen from 101° to about 108°. MM. Delaroche and Berger tried several experiments on different species of animals, in order to ascertain the highest temperature to which the body could be raised without the destruction of life, by inclosing them in air heated from 122° to 201°, until they died: the result was very uniform, the temperature of the body at the end of the experiment only varying in the different species between 11° and 13° above their natural standard: whence it may be inferred, that an elevation to this degree must be fatal. This

* The wonderful feats performed by many individuals from time to time,—of dipping the hand into melted lead, laying hold of a red-hot iron, &c.,—have been recently shown by M. de Boutigny to be explicable upon very simple principles. For in all such cases, a thin film of aqueous fluid in the 'spherical state' intervenes between the skin and the heated surface; and a hand which is naturally damp, or which has been slightly moistened, may be safely passed into the stream of molten iron as it flows from the furnace; as was demonstrated by M. de Boutigny at the recent meeting of the British Association at Ipswich (1851).

† "Expériences sur les Effets qu'une forte Chaleur produit sur l'Economie;" Paris. 1805: and "Journal de Physique," tomes lxiii., lxxi., et lxxvii.

‡ "Philosophical Transactions," 1775.

elevation would be attained comparatively soon in a moist atmosphere; partly because of the greater conducting power of the medium: but principally on account of the check which is put upon the vaporization of the fluid secreted by the skin. Even here, however, custom and acquired constitution have a very striking influence; for whilst the inhabitants of this country are unable to sustain, during more than 10 or 12 minutes, immersion in a vapour-bath of the temperature of 110° or 120°, the Finnish peasantry remain for half an hour or more in a vapour bath the temperature of which finally rises even to 158° or 167°.—Accurate experiments are yet wanting, to determine the influence of humidity on the effects of *cold* air. From experiments on young Birds incapable of maintaining their own temperature, of which some were placed in cold dry air, and others in cold air charged with moisture, it was found by Dr. Edwards that the loss of heat was in both instances the same; the effect of the evaporation from the surface in the former case, being counterbalanced in the latter by the depressing influence of the cold moisture. This influence, the existence of which is a matter of ordinary experience, is probably exerted directly upon the nervous system.

655. Having thus considered the general facts which indicate the faculty possessed by the living system, in the higher Animals, of keeping up its temperature to an elevated standard, and of preventing it from being raised much beyond it by any degree of external heat, we have next to inquire to what this faculty is due.—In forming an opinion upon this point, it is of fundamental importance to bear in mind, that the production of Heat is not peculiar to Animals, but is exhibited also by Plants, in parts in which certain vital operations that involve the production of carbonic acid, are taking place with unusual rapidity, and under circumstances which tend to prevent the dissipation of the heat thus generated. This is pre-eminently the case during the periods of germination and flowering; as may be seen in the act of malting, where a number of germinating seeds being heaped together, the thermometer in the midst of them has been observed to rise to 110°; whilst during the flowering of the Arum tribe, whose blossoms are crowded together on spadixes, and these are enclosed in protective spathes, a thermometer placed in the midst of twelve spadixes has been seen to rise to 121°, the temperature of the surrounding air being only 66°.* In all such cases, the elevation of temperature is found to be a very constant ratio to the amount of carbonic acid which is produced by the union of atmospheric oxygen with carbon set free from the vegetable tissues;† so that it is scarcely possible to entertain a reasonable doubt, that the production of Heat in Plants is dependent upon a process of slow combustion.—When the general phenomena of Calorification in Animals are carefully examined, they are found to harmonise with this view. Throughout the whole kingdom, a close and exact conformity may be perceived, between the amount of Oxygen consumed and of Carbonic acid given off, and the

* See "Princ. of Phys., Gen. and Comp.," §§ 615, 616.

† This has been made yet more certain by the recent observations of M. Garreau ("Ann. des Sci. Nat.," 3me série, Botan., tom. xvi. p. 250), who has noted the temperature of these spadixes, hour by hour, during the 'paroxysm' of flowering, and the quantity of oxygen consumed during the same periods, with the following result; the amount of heat developed being expressed by the number of degrees (Cent.) shown by the thermometer above the

degree of Heat liberated. In the cold-blooded animals, whose temperature is almost entirely dependent upon that of the surrounding element, the respiration is feeble; being carried on, for the most part, through the medium of water. In the warm-blooded Vertebrata, however, which have the power of keeping up the heat of their bodies to an elevated standard, even when that of the surrounding air is far beneath it, the quantity of oxygen consumed is very large; and that required by Birds is more, in proportion to their size, than that employed by Mammalia, as we should expect from the more elevated temperature of the former. In the class of Insects, we have a very remarkable illustration of the same general fact. It appears, from the researches of Mr. Newport,* that Insects, during their larva and pupa states, and even in their perfect condition when at rest, are to be regarded as truly cold-blooded animals; their temperature rising and falling with that of the surrounding medium, and being at no time more than a degree or two above it. In a state of activity, however, the temperature of the body attains a considerable elevation; frequently as much as 10° or 15° above that of the air. It must be remembered that, owing to their larger extent of surface in proportion to their bulk, small animals are cooled much more rapidly than large ones; and the temperature of insects would probably rise much higher, if it were not for the loss they are thus continually experiencing, which is greatly increased by the action of the wings. In one of Mr. N.'s experiments, a single Humble-bee, in a state of violent excitement, communicated to three cubic inches of air as much as 4° of heat within five minutes; its own temperature being raised 7° in the same time. When several individuals in a state of excitement, however, are clustered together, so that the loss of heat is prevented, the elevation of temperature is much more considerable; thus a thermometer introduced among seven "nursing-bees" stood at $92\frac{1}{2}$°, whilst the external air was only 70°; and the temperature of a hive was raised by disturbing it, during winter, from $48\frac{1}{2}$° to 102°, the temperature of the air being only $34\frac{1}{2}$° at the time.—In all these instances, the amount of Oxygen consumed bears an exact proportion to that of the Heat evolved.

656. We have seen that in Man, as in the lower animals, exercise has

temperature of the surrounding air, and the quantity of oxygen consumed being stated in multiples of the volume of each spadix.

| | No. 1. | | No. 2. | | No. 3. | |
|---|---|---|---|---|---|---|
| | *Heat produced.* | *Oxygen consumed.* | *Heat produced.* | *Oxygen consumed.* | *Heat produced.* | *Oxygen consumed.* |
| 1st hour . . . | 3·2 | 1·11 | 4·2 | 16·5 | 3·5 | 10·0 |
| 2nd hour . . | 5·3 | 16·2 | 7·2 | 21·1 | 6·1 | 15·5 |
| 3rd hour . . . | 7·8 | 21·4 | 9·8 | 27·7 | 8·6 | 21·1 |
| 4th hour . . | 8·3 | 28·5 | 8·4 | 18·9 | 10·2 | 31·1 |
| 5th hour . . . | 6·0 | 14·2 | 4·8 | 12·2 | 9·8 | 18·9 |
| 6th hour . . | 2·7 | 5·7 | 2·7 | 5·5 | 5·7 | 7·7 |
| Mean . . . . | 5·5 | 16·1 | 6·1 | 16·9 | 7·3 | 17·3 |

* "Philosophical Transactions," 1837.

a considerable though a more limited effect in producing an elevation of temperature; and, that this is not merely due to the acceleration of the circulation, is shown by the fact, that the exercise of a particular muscle will cause an increase in the heat liberated from it (§ 330).* It may be stated as a general fact, that every change in the condition of the organic components of the body, in which their elements enter into new combinations with oxygen, must be a source of the development of Heat. And as we have seen that a considerable part of the carbonic acid and water which are exhaled in Respiration, is formed within the body by the metamorphosis of its own tissues, and that this metamorphosis is promoted by the active exercise of the nervo-muscular apparatus, it follows that in animals whose habits of life are peculiarly active, whilst the temperature of the surrounding medium is sufficiently high to prevent its exerting any considerable cooling influence over them, the combustive process thus maintained may be adequate for the maintenance of the temperature of the body at its normal standard. This seems to be the case with the great Carnivorous quadrupeds of warm climates, and with certain races of Men who lead a life of incessant activity like theirs. But whenever the cooling influence of the atmosphere is greater, or the retrograde metamorphosis of tissue takes place with less activity, some further supply of heat-producing material is required; and this is derived either directly from the food, or from a store previously laid up in the body. Although the albuminous and gelatinous components of the food, may be made, by decomposition within the body, to yield saccharine and oleaginous compounds, which serve as an immediate *pabulum* to the combustive process, yet this metamorphosis involves a great waste of valuable nutritive material; and the needed supply is much more advantageously derived at once from those farinaceous or oleaginous substances, which are furnished in abundance by the Vegetable kingdom, the latter also by the Animal. No reasonable doubt can any longer be entertained, that the production of Heat by the combustive process is the purpose to which these substances are destined to be subservient in the bodies of Herbivorous animals and of Man; and the results of experience in regard to their relative heat-producing powers, are in precise accordance with the indications afforded by their chemical composition (§ 401).

657. Our knowledge of the dependence of all the vital processes in warm-blooded animals upon the Heat of their bodies, and of the dependence of their calorifying power upon the due supply of material for the combustive process, has received some remarkable additions from the experiments of M. Chossat upon Starvation.† He found that Birds, when totally deprived of food and drink, suffered a progressive, though slight, daily diminution of temperature. This diminution was not so much shown by a fall of their maximum heat, as by an increase in the

* It was affirmed by Dr. Granville ("Phil. Trans.," 1825) that the temperature of the uterus during parturition sometimes rises as high as 120°. In some observations made at the Philadelphia Hospital, however, at the desire of Prof. Dunglison, the temperature of the uterus was not found to be much above that of the vagina; the former being, in three cases, 100°, 102°, and 106°, whilst the latter was 100°, 100°, and 105°. (Prof. Dunglison's "Human Physiology," 7th edit., vol. ii. p. 226).

† "Recherches Expérimentales sur l'Inanition," Paris, 1843; an analysis of this work will be found in the "Brit. and For. Med. Rev.," April, 1844.

diurnal variation, which he ascertained to occur even in the normal state (§ 651, *b*). The average variation in the *inanitiated* state, was about 6° (instead of $1\frac{1}{2}$°), gradually increasing as the animal became weaker; moreover, the gradual rise of temperature, which should have taken place between midnight and noon, was retarded; whilst the fall subsequently to noon commenced much earlier than in the healthy state; so that the *average* of the whole day was lowered by about $4\frac{1}{2}$° between the *first* and the *penultimate* days of this condition. On the *last* day, the production of heat diminished very rapidly, and the thermometer fell from hour to hour, until death supervened; the whole loss on that day being about 25° Fahr., making the *total* depression about $29\frac{1}{2}$°. This depression appears, from the considerations to be presently stated, to be the *immediate* cause of Death.—On examining the amount of loss sustained by the different organs of the body, it was found that 93 per cent of the *Fat* had disappeared; being all, in fact, which *could* be removed; whilst the nervous centres scarcely exhibited any diminution in weight (§ 416). From the constant coincidence between the entire consumption of the fat, and the depression of temperature,—joined to the fact that the duration of life under the inanitiating process evidently varied (other things being equal) with the amount of fat previously accumulated in the body,—the inference seems irresistible, that the calorifying process depended chiefly, if not entirely, on the materials supplied by this substance. Whenever, therefore, the store of combustible matter in the system was exhausted, the inanitiated animals died, by the cooling of their bodies consequent upon the loss of calorifying power.

658. That this is the real explanation of the fact, is shown by the results of a series of very remarkable experiments performed by M. Chossat, with the purpose of testing the correctness of this view. When inanitiated animals whose death seemed impending (in several instances death actually took place, whilst the preliminary processes of weighing, the application of the thermometer, &c., were being performed), were subjected to artificial heat, they were almost uniformly restored from a state of insensibility and want of muscular power to a condition of comparative activity; their temperature rose, their muscular power returned, they flew about the room and took food when it was presented to them; and if the artificial assistance was sufficiently prolonged, and they were not again subjected to the starving process, most of them recovered. If they were left to themselves too early, however, the digestive process was not performed, and they ultimately died. Up to the time when they began to take food, their weight continued to diminish; the secretions being renewed, under the influence of artificial heat, sometimes to a considerable amount. It was not until digestion had actually taken place (which, owing to the weakened functional power, was commonly many hours subsequently to the ingestion of the food), that the animal regained its power of generating heat; so that, if the external source of heat was withdrawn, the body at once cooled: and it was not until the quantity of food actually *digested* was sufficient to support the wants of the body, that its independent power of calorification returned. It is to be remembered that, in such cases, the resources of the body are on the point of being completely exhausted, when the attempt at re-animation is made; consequently it has nothing whatever to fall back upon; and the leaving it

to itself *at any time* until fresh resources have been provided for it, is consequently as certain a cause of death, as it would have been in the first instance.

659. It can scarcely be questioned, from the similarity of the phenomena, that Inanitiation, with its consequent depression of temperature, is the immediate cause of death in various diseases of Exhaustion: and it seems probable that there are many cases, in which the depressing cause is of a temporary nature, and in which a judicious and timely application of artificial heat might prolong life until it has passed off, just as artificial respiration is serviceable in cases of narcotic poisoning (§ 208). It is especially, perhaps, in those forms of Fever, in which no decided lesion can be discovered after death, that this view has the strongest claim to reception; and the beneficial result of the administration of Alcohol in such conditions, and the large amount in which it may be given with impunity, may probably be accounted for on this principle. That it acts as a specific stimulus to the nervous system, cannot be doubted from its effects on the healthy body; but that it serves as a *fuel* to keep up the calorifying process, appears equally certain. Its great efficacy in such cases seems to depend upon the readiness with which it will be taken into the circulation, by a simple act of endosmotic imbibition, when the special Absorbent process, dependent upon the peculiar powers of the cells of the villi (§ 461), are in abeyance. There is no other combustible fluid, whose miscibility and whose density, relatively to that of the Blood, will permit of its rapid absorption by the simple physical process adverted-to.*

660. That the oxidation of certain components of the food or of the tissues is the fundamental source of Animal Heat, is further indicated by the close conformity which we everywhere find between the activity of the Respiratory process and the amount of Heat which is generated; and this not merely when we compare different tribes of animals with each other, but also when we compare the amount of oxygen absorbed and of carbonic acid exhaled by the same individuals under different degrees of external temperature (§ 564, *a*). For we find that the system possesses within itself a regulating power, by which the combustive process is augmented in activity when the cooling influence of the surrounding medium is considerable, so that this influence is resisted; whilst the internal fire (so to speak) is slackened, whenever the temperature of the outer air rises so much, as to render the same generation of heat no longer requisite. The appetite for food, and especially for those particular forms of it which best afford the combustive pabulum, varies in the same degree; and thus, when supplied with appropriate nutriment, Man is able to brave the severest cold, without suffering any considerable depression in his bodily temperature.—It would seem that the Cutaneous Respiration, small as it is, promotes those molecular changes on which the maintenance of Animal Heat depends; for it was found by MM. Becquerel and Breschet,† that when the hair of Rabbits was shaved off, and a composition of glue, suet, and resin (forming a coating impermeable to the air) was applied to the

* The Author has stated the very striking results of observations which he has had the opportunity of making upon this point, in his Prize Essay "On the Use and Abuse of Alcoholic Liquors," § 215.

† "Comptes Rendus," Oct., 1841. These experiments have been repeated and confirmed by Magendie ("Gazette Médicale," Dec. 6, 1843).

whole surface, the temperature rapidly fell, notwithstanding the obstacle thus offered to the evaporation of the sweat, whereby, it might be supposed, the temperature of the body would be considerably elevated. In the first rabbit, which had a temperature of 100° before being shaved and plastered, it had fallen to 89½° by the time the material spread over him was dry. An hour after, the thermometer placed in the same parts (the muscles of the thigh and chest) had descended to 76°. In another rabbit, prepared with more care, by the time that the plaster was dry, the temperature of the body was not more than 5½° above that of the surrounding medium, which was at that time 69½°; and in an hour after this, the animal died.—These experiments place in a very striking point of view the importance of the cutaneous surface as a respiratory organ, even in the higher animals; and they enable us to understand how, when the secreting power of the lungs is nearly destroyed by disease, the heat of the body is kept up to its natural standard by the action of the Skin. A valuable therapeutic indication, also, is derivable from the knowledge which we thus gain, of the importance of the cutaneous respiration; for it leads us to perceive the desirableness of keeping the skin moist, in those febrile diseases in which there is great heat and dryness of the surface, since secretion cannot properly take place through a dry membrane. Of the relief afforded by cold or tepid sponging in such cases, experience has given ample evidence.

661. It has been held that the Chemical theory of Calorification is insufficient to account for the total amount of Heat generated by a warm-blooded animal in a given time; this assertion being founded upon the experimental results obtained by M. Dulong. It has been shown by Prof. Liebig, however, that the estimates originally made require correction for the true calorific equivalents of carbon and hydrogen; and that, this correction having been made, the heat produced by the combustion of the Carbon which is contained in the carbonic acid expired, and by the combustion of such a proportion of the Hydrogen contained in the exhaled water as may be fairly considered to have undergone oxygenation within the system (§ 569), proves to be adequate to compensate for that which would be dissipated by the evaporation of all the water transpired from the skin and lungs, and also to maintain the temperature of the body itself in an atmosphere of ordinary coolness.* And to the combustion-heat of carbon and hydrogen, we should also add that of those relatively-minute quantities of Phosphorus and Sulphur, which also undergo oxidation within the system, whereby a small additional amount of heat must be generated.—Through whatever diversity of combinations or successive stages of oxidation these elements respectively pass, in their progress to complete or final oxidation, it may be regarded as an indisputable fact, that *they give out precisely the same amount of heat in the whole, as if they had undergone the most rapid combustion in pure oxygen;* and thus we may look to almost every molecular change in the body, although pre-eminently to those which are concerned in the *disintegration* of its textures and in the elimination of their products by Respiration, as participating in the function of Calorification.

662. It cannot be denied, however, that there are certain phenomena

* See P. of Liebig's "Animal Chemistry," 3rd edit., p. 44.

which seem at first sight to be completely opposed to this doctrine, and which can scarcely be explained in accordance with it, save by a considerable modification in our usual ideas. The class of facts to which reference is here made, are those which indicate that the Nervous system has a very important concern in the process, and that it is, in fact, one of the immediate instruments in the development of heat. Thus it was experimentally shown by Sir B. Brodie,* that when the Brain is cut-off from the spinal cord, or its functions are suspended by the agency of a narcotic, and artificial respiration is practised, so that the circulation is maintained, the body not only loses heat rapidly, but may even cool *more rapidly* than the body of an animal similarly treated, but in which artificial respiration is not performed. Now it is certainly true, as was subsequently pointed-out by Drs. Wilson Philip and Hastings,† and by Dr. C. Williams,‡ that the effect of the artificial performance of respiration depends in some degree upon the mode in which it is accomplished; for that if, as in most of Sir B. Brodie's experiments, the insufflation be repeated 30 times or more in a minute, the cooling effect of the air thus introduced is greater than the warming effect of the imperfect respiratory change to which it becomes subservient; whilst if the insufflation be repeated only 12 times in a minute, the cooling of the body, as compared with that of a body in which the circulation is not thus maintained, is retarded, instead of being accelerated. But still it is evident from Sir B. Brodie's experiments, that the withdrawal of the influence of the Encephalon has a positively depressing effect upon the Calorific function; for the rapid fall of temperature took place even in cases in which the amount of carbonic acid exhaled during the performance of artificial respiration, was fully equal to the normal quantity; and the subsequent experiments of MM. Le Gallois§ and Chossat|| are decidedly confirmatory of this conclusion, whilst they extend it to other lesions of the Nervous centres, the influence of which upon the calorific function appears to be proportional to their severity.—Various pathological phenomena, moreover, indicate that the withdrawal of nervous influence from any part of the body usually tends to produce a depression of its temperature, and this especially in the extremities; thus Mr. H. Earle ¶ found the temperature of paralysed limbs slightly lower than that of sound limbs; so Prof. Dunglison has noticed that in one case of hemiplegia of five months' standing, the temperature of the axilla was $96\frac{1}{2}°$ on the sound side, and 96° on the paralysed, whilst that of the hand was 87° on the sound side and only $79\frac{1}{2}°$ on the paralysed; and in another case of only a fortnight's duration, the temperature of the axilla was 100° on the sound side, and only $98\frac{1}{4}°$ on the paralysed, whilst that of the hand was 94° on the sound side, and 90° on the paralysed.**—But it is a remarkable fact, that the disturbance of temperature produced by severe injuries of the

* "Philosophical Transactions," 1811, 1812; and "Physiological Researches."

† See Dr. Wilson Philip's "Experimental Enquiry into the Laws of the Vital Functions," 3rd edit., p. 180.

‡ "Edinb. Med.-Chir. Trans." vol. ii. p. 192.

§ "Annales de Chimie," 1817; and "Œuvres de M. Le Gallois," tom. ii.

|| "Mémoire sur l'Influence de Systéme Nerveux sur la Chaleur Animale."

¶ "Medico-Chirurgical Transactions," vol. vii.

** "Human Physiology," 7th edit., vol. ii. p. 238.

Nervous system, occasionally shows itself in the opposite direction. Thus it has been noticed by many experimenters, that one of the first effects of division of the spinal cord in the back, in warm-blooded animals, is to *raise* the temperature of the posterior part of the body, this elevation continuing for some hours. A case is recorded by Sir B. Brodie, in which, the spinal cord having been so seriously injured in the lower part of the cervical region that the whole of the nerves passing-off below were completely paralysed, the heat of the body, as shown by a thermometer placed on the inside of the groin, was not less than 111°; and this notwithstanding that the respiratory function was very imperfectly performed, the number of inspirations being considerably reduced, and the countenance being livid.* And Prof. Dunglison states that, notwithstanding the usual depression of the thermometer on the hemiplegic side, it is not unfrequently found to be more elevated than on the sound side.† According to the recent experiments of M. Cl. Bernard‡ it appears that an elevation of temperature constantly takes place on one side of the face, when the trunk which unites the Sympathetic ganglia of the neck on that side is cut through; this increase being not only perceptible to the touch, but showing itself by a thermometer introduced into the nostrils or ears, even to the extent of from 7° to 11° Fahr. When the superior cervical ganglion is removed, the same effect is produced, but with yet greater intensity. This difference is maintained for many months, and is not connected with the occurrence of inflammation, congestion, œdema, or any other pathological change in the part; moreover it is not prevented from manifesting itself by the division of any of the cerebro-spinal nerves of the face. It is remarkable that the sensibility of the parts thus affected should be no less augmented than their temperature.

663. The influence which conditions of the Nervous System are thus shown to possess over the function of Calorification, has led some Physiologists and even Chemists to the conclusion that the production of Heat is essentially dependent upon Nervous agency, of which it is one of the manifestations. But, as Prof. Liebig justly observes, "if this view exclude chemical action, or changes in the arrangement of the elementary particles, as a condition of nervous agency, it means nothing else than to derive the presence of motion, the manifestation of force, from nothing. But no force, no power, can come of nothing."§ That the production of heat in living bodies may take place without any possible assistance from Nervous agency, is manifest from the phenomena of Vegetable heat already referred-to (§ 655); and there can be no reasonable doubt, that the source of this production is a true combustive process. And the evidence afforded by the post-mortem production of heat in the Human subject (§ 652) conclusively points to the same result; more particularly as the elevation of temperature observed in the brain was uniformly *less* than that which was manifested in other large organs.—But the phenomena just enumerated (and many others that might be cited) can scarcely be accounted-for, without admitting that the Nervous system exerts an

* "Medical Gazette," June, 1836; and "Physiological Researches," p. 121.

† "Amer. Med. Intelligencer," Oct. 18, 1838.

‡ "Gazette Médicale," Fevr. 21, 1852.

§ "Animal Chemistry," 3rd edit., p. 39.

important modifying power upon the temperature of the body, which may be either elevated or depressed through its agency; and the question now arises, whether this operation takes place through the influence which the Nervous system exerts over the molecular processes of Nutrition, Secretion, &c., or through some more direct method. It can scarcely be denied that the first of these channels affords not merely a possible, but also a probable means, for the exercise of such influence; but still it is difficult to conceive that any great effect can be thus produced, since, as already shown, it is not so much in the growth as in the disintegration of textures, that heat is produced by the oxidation of their components. On the other hand, from the close relation which has been shown to exist between the Vital and Physical forces (CHAP. III., Sect. 2), it can scarcely be regarded as improbable that the Nervous force, generated by molecular changes in the Nervous substance, may manifest itself under the form of Heat, just as we know that it manifests itself (as in the Electric fishes) under that of Electricity.* And thus it is quite conceivable that one mode in which alimentary materials may be applied to the maintenance of Animal Heat, may consist in their subservience to these molecular changes, which seem to take place in the Nervous substance with more activity than in any other tissue; and thus a large measure of caloric may be generated through the immediate instrumentality of the Nervous system, notwithstanding that the ultimate source of its development lies (as in the Chemical theory) in the oxidation of the elements of the food.—Such an hypothesis will be found consistent, the Author believes, with all the well-ascertained facts of the case; for whilst it assigns their full value to all those proofs, which establish (in his mind) the necessary dependence of Calorification upon the changes to which the Respiration is subservient, and thus upon the supply of combustive material on the one hand and of oxygen on the other, it also assigns a definite *modus operandi* to the Nervous system, as an instrument largely concerned in the production and distribution of the heat thus generated, —this *modus operandi*, moreover, being in such complete harmony with the other manifestations of Nervous power, that its existence might almost have been predicated upon general considerations.†

664. We have now to inquire whether the power of generating Heat is possessed by the Human subject in an equal degree at all ages; this question being very different from that of the usual temperature of the body at the various periods of life; since an individual who can maintain a high temperature when the surrounding air is moderately warm, may have very little power of bearing continued exposure to severe cold. Important analogical evidence on this point has been supplied by the experiments of Dr. W. F. Edwards upon the lower Mammalia, Birds, &c.‡ It appears from these to be a general fact that, the younger the animal, the less is its independent calorifying power. The development of the embryo of oviparous animals is entirely dependent upon the amount of external warmth supplied to it; and there are many kinds of Birds, which, at the

* See "Princ. of Phys., Gen. and Comp.," §§ 635–639.

† See the Author's Memoir 'On the Mutual Relations of the Vital and Physical Forces,' in "Phil. Trans.," 1850.

‡ "On the Influence of Physical Agents on Life," Part iii. Chap. i.

time they issue from the egg, are so deficient in the power of generating heat, that their temperature rapidly falls when they are removed from the nest and placed in a cold atmosphere. It was shown by collateral experiments, that the loss of heat was not to be attributed to the absence of feathers, nor to the extent of surface exposed in comparison with the bulk of the body; and that nothing but an absolute deficiency in the power of generating it, would account for the fall of temperature. This is quite conformable to facts well ascertained in regard to Mammalia. The fœtus, during intra-uterine life, has little power of keeping up its own temperature; and in many cases it is much dependent on external warmth, for some time after birth. The degree of this dependence, however, differs greatly in the various species of Mammalia, as among Birds; being less, in proportion as the general development is advanced. Thus, young Guinea-pigs, which can run about and pick up food for themselves, almost as soon as they are born, are from the first independent of parental warmth; whilst on the other hand, the young of Dogs, Cats, Rabbits, &c., which are born blind, and which do not, for a fortnight or more, acquire the same development with the preceding, rapidly lose their heat when withdrawn from contact with the body of the mother.—In the Human species, it is well known that external warmth is necessary for the Infant, its body rapidly losing heat when exposed to the chilling influence of a low temperature; but the fact is too often neglected (under the erroneous idea of hardening the constitution) during the early years of childhood. It is to be carefully remembered, that the development of Man is slower than that of any other animal, and that his calorifying power is closely connected with his general bodily vigour; and though the infant becomes more independent of it as development advances, it is many years before the standard can be maintained without assistance, throughout the ordinary vicissitudes of external temperature. Especial care is required with regard to the maintenance of the bodily heat by artificial warmth, in the case of children prematurely born; for the earlier the period of embryonic life, the less is the power of calorification that exists for some time after birth. The temperature of a seven months' child, though well swathed and near a good fire, was found by Dr. W. Edwards, within two or three hours after its birth, to be no more than 89·6°. And in some of the recorded instances in which the birth has taken place before the completion of the sixth month, it has not been found possible to maintain the warmth of the infant by exposure to the radiant heat of a fire, the contact of the warm body of another person being the only effectual means of keeping-up its temperature.—The fullest measure of calorifying power is possessed by adults; but even in them it is sometimes weakened by previous exertion, so that death by the cooling of the body may occur when the body is exposed to cold of no great intensity, but in a state of exhaustion of nervous power; a fact which remarkably confirms the views advanced in the preceding paragraph. A decrease of calorifying power takes place in advanced age. Old people complain that their "blood is chill;" and they suffer greatly from exposure to cold, the temperature of the whole body being lowered by it.—These facts have a very interesting connection with the results of statistical inquiries, as to the average number of deaths at different seasons; the following are recorded by M.

Quetelet,* as occurring at Brussels, the *mean* monthly mortality at each age being reckoned as 100.

| | First Month. | 2—3 Years. | 8—12 Years. | 25—30 Years. | 50—65 Years. | 90 Years and above. |
|---|---|---|---|---|---|---|
| January . . | 1·39 | 1·22 | 1·08 | 1·05 | 1·30 | 1·58 |
| February . . . | 1·28 | 1·13 | 1·06 | 1·04 | 1·22 | 1·48 |
| March . . . | 1·21 | 1·30 | 1·27 | 1·11 | 1·11 | 1·25 |
| April . . . | 1·02 | 1·27 | 1·34 | 1·06 | 1·02 | 0·96 |
| May . . . | 0·93 | 1·12 | 1·21 | 1·02 | 0·93 | 0·84 |
| June . . . | 0·83 | 0·94 | 0·99 | 1·02 | 0·85 | 0·75 |
| July . . . | 0·78 | 0·82 | 0·88 | 0·91 | 0·77 | 0·64 |
| August . . . | 0·79 | 0·73 | 0·82 | 0·96 | 0·85 | 0·66 |
| September . . | 0·86 | 0·76 | 0·81 | 0·95 | 0·89 | 0·76 |
| October . . . | 0·91 | 0·78 | 0·76 | 0·93 | 0·90 | 0·74 |
| November . . | 0·93 | 0·91 | 0·80 | 0·97 | 1·00 | 1·03 |
| December . . . | 1·07 | 1·01 | 0·96 | 0·97 | 1·15 | 1·29 |

We see from this table that, during the first months of infant life, the external temperature has a very marked influence; for the average mortality during each of the three summer months being 80, that of January is nearly 140, and the average of February and March is 125. This is confirmed by the result obtained by MM. Villermé and Milne-Edwards in their researches on the mortality of the children conveyed to the Foundling Hospitals in the different towns in France; for they not only ascertained that the mortality is much the greatest during the first three months in the year, but also that it varies in different parts of the kingdom, according to the relative severity of the winter.† As childhood advances, however, the winter mortality diminishes, whilst that of the spring undergoes an increase; this is probably due to the greater prevalence of certain epidemics at the latter season; for the same condition is observed, in a still more remarkable degree, between the ages of 8 and 12 years,—the time when children are most severely affected by such epidemics. As the constitution acquires greater vigour, and the bodily structure attains its full development, the influence of the season upon mortality becomes less apparent; so that at the age of from 25 to 30 years, the difference between the summer and winter mortality is very slight. This difference reappears, however, in a very marked degree, at a later period, when the general vigour, and the calorifying power, undergo a gradual diminution. Between the ages of 50 and 65 it is nearly as great as in early infancy; and it gradually becomes more striking, until, at the age of 90 and upwards, the deaths in January are 158, for every 74 in July (a proportion of $2\frac{1}{2}$ to 1); and the average of the three winter months is 145, whilst that of the three summer months is only 68, or less than one-half.—The results of the comparisons which have now been

* "Essai de Physique Sociale," tom. i. p. 197.

† Dr. Emerson has shown that, in the Southern and Middle States of North America, the *high summer* temperature is the greatest cause of infant mortality; the proportion of deaths during the first year of childhood, occurring in the months of June, July, and August, being about *four* times greater than that occurring during the same months in any subsequent year up to the age of 20. The winter mortality under the second year scarcely exceeds the average of subsequent years. ("Amer. Journ. of Med. Sci.," Nov., 1831).

carried-out for many successive years, in the Reports of the Registrar General, between the variations in the weekly rate of mortality in the Metropolis and the range of atmospheric temperature, present a close coincidence with the foregoing: it being especially to be noted, that the rate of mortality (save during the prevalence of any fatal epidemic) is almost invariably the highest during the winter months; that the increase of deaths at that period is most marked amongst children and old people; and that any extraordinary severity of winter cold constantly produces a great augmentation in the mortality, the weekly number of deaths rising from the average of 1000 (or thereabouts) to 1200, when the mean temperature of the twenty-four hours falls a degree or two lower than the freezing-point.

665. Having thus considered the means by which the degree of Heat necessary for the performance of the functions of the Human system is generated, we have to inquire how its temperature is prevented from being raised too high; in other words, what *frigorifying* means there are, to counterbalance the influence of causes, which in excess would otherwise be fatal, by raising the heat of the body to an undue degree (§ 654). How is it, for example, that, when a person enters a room whose atmosphere is heated to one or two hundred degrees above his body, the latter does not partake of the elevation, even though exposed to the heat for some time? Or, since the inhabitants of a climate, where the thermometer averages 100° for many weeks together, are continually generating additional heat in their own bodies, how is it that this does not accumulate, and raise them to an undue elevation?—The means provided by Nature for cooling the body when necessary, are of the simplest possible character. From the whole of its soft moist surface, simple *Evaporation* will take place at all times, as from an inorganic body in the same circumstances; and the amount of this will be regulated merely by the condition of the atmosphere, as to warmth and dryness. The more readily watery vapour can be dissolved in atmospheric air, the more will be lost from the surface of the body in this manner. In cold weather, very little is thus carried off, even though the air be dry: and a warm atmosphere, already charged with dampness, will be nearly as ineffectual. But simple evaporation is not the chief means by which the temperature of the body is regulated. The Skin, as already mentioned (§ 646), contains a large number of glandulæ, the office of which is to secrete an aqueous fluid; and the amount of this *Exhalation* appears to depend solely or chiefly upon the *temperature* of the surrounding air. Thus, when the external heat is very great, a considerable amount of fluid is transuded from the skin; and this, in evaporating, carries off a large quantity of the free caloric, which would otherwise raise the temperature of the body. If the atmosphere be hot and dry, and also be in motion, both exhalation and evaporation go on with great rapidity. If it be cold, both are checked, the former almost entirely so; but, if it be dry, some evaporation still continues. On the other hand, in a hot atmosphere, saturated with moisture, exhalation continues, though evaporation is almost entirely checked; and the fluid poured out by the exhalant glands accumulates on the skin. There is reason to believe that the secretion continues, even when the body is immersed in water, provided its temperature be high.—We learn from these facts the great importance of not suddenly checking Exhala-

tion, by exposure of the surface to cold, when the secretion is being actively performed; since a great disturbance of the circulation will be likely to ensue, similar to that which has been already mentioned, as occurring when other important secretions are suddenly suspended.

### 3. *Evolution of Light.*

666. Although the evolution of Light from the living Human subject is an exceptional phenomenon, which has only been observed in morbid states of the body, yet its occasional occurrence is fraught with interest to the Physiologist, on the one hand from its relation to the Luminosity so common among the lower animals, and on the other from the indications which it affords of the possibility of the formation, even during life, of peculiar phosphuretted compounds, which, being products of incipient decomposition, have been usually supposed to be generated only after death.—There is no doubt that luminous exhalations frequently ascend from burial-grounds; and that the superstitions of many nations respecting 'corpse-lights' have to this extent a foundation in fact. A very decided luminosity has been observed to proceed from dissecting-room subjects, the light thus evolved being sufficient to render the forms of the bodies, as well as those of muscles and other dissected parts (which are peculiarly bright), almost as distinct as in the day light. That this proceeds from the production of a peculiar phosphorescent compound, is shown by the fact, that the luminosity may be communicated to the fingers or to towels, &c., by contact with the luminous surfaces.*—Dr. W. Stokes narrates the case of a patient who was under his observation, some years since, in the Old Meath Hospital, having been admitted on account of an enormous cancer in her breast, which was in an advanced stage of ulceration, the edges being irregular and everted; every part of the base and edges of this cavity was strongly phosphorescent, the light being sufficient to enable the figures on a watch-dial to be distinguished within a few inches; and here also it appeared that the luminosity was due to a particular exudation from the exposed surface. Three cases are recorded by Sir H. Marsh, in which an evolution of light took place from the living body, without any such obvious source of decomposition; all the subjects of these cases, however, were in the last stage of phthisis; and it cannot be doubted that here, as in other diseases of exhaustion, incipient disintegration was taking place during the later periods of life (§ 418). The light in each case is described as playing around the face, but not as directly proceeding from the surface; and in one of these instances, which was recorded by Dr. D. Donovan,† the luminous appearance was not only perceptible over the head of the patient's bed, but luminous vapours passed in streams through the apartment. It can scarcely be doubted that it was here the *breath* which contained the luminous compound, more especially as in one of the cases it was observed to have a very peculiar smell; and the probability that the luminosity was due to the presence of phosphorus in progress of slow

* See Sir Herbert Marsh on "The Evolution of Light from the Living Human Subject" (Dublin, 1842), p. 20.—From this interesting pamphlet, most of the statements in this paragraph are derived.

† "Dublin Medical Press," Jan. 15, 1840.

oxidation, is greatly increased by the fact already referred-to (§ 570), that the injection of phosphuretted oil into the blood-vessels gives rise to a similar appearance. In repeating this experiment, Sir H. Marsh states that when half an ounce of olive oil, holding two grains of phosphorus in solution, was injected into the crural vein of a dog, a dense white vapour began to issue from the nostrils even before the syringe was completely emptied, which became faintly luminous on the removal of the lights: and the injection being repeated with the same quantity, the expiration immediately became beautifully luminous, resembling jets of pale-coloured flame pouring forth from the nostrils of the animal. And the luminosity which has been occasionally observed in the urine,* may fairly be imputed to an increase in the quantity of unoxidized phosphorus which it seems normally to contain; its liberation taking place at a more rapid rate than its conversion into phosphoric acid (§ 641), either through excessive excretion or through impeded respiration. A case has been recorded by Kaster (loc. cit.) in which the body-linen was rendered luminous by the perspiration, after any violent exercise; and here, too, the cause may be presumed to have been the same.—On the whole, then, we may conclude the occasional evolution of Light from the Human subject, to be the consequence (when not an *electrical* phenomenon) of the production of a phosphorescent compound at the expense of the disintegrating tissues; which compound passes off through one of the ordinary channels of excretion.

## 4. *Evolution of Electricity.*

667. When the vast variety of changes of condition to which the components of the living body are subjected during the performance of its vital operations, and the impossibility of the occurrence of any of these without some disturbance of electric equilibrium,† are duly considered, the wonder is, not that such disturbance should be occasionally so considerable as to make itself apparent, but that it should be ordinarily so obscure as only to be detected by the most careful search, and with the assistance of the most delicate instruments.—The researches of Prof. Matteucci, M. du Bois-Reymond, and others, however, have now made it apparent, that there are no two parts of the body (save those which correspond on the opposite sides), whose electrical condition is

* "Casper's Wochenshrift," 1849, No. 15.—A case has been recently put on record (Büchner's Repert. B. viii. p. 342), in which the urine and semen of a patient who was under treatment for impotence and spermatorrhœa, and who was employing phosphorus as a remedy both internally and externally, were observed to be luminous.

† There is probably no instance of *chemical union* or decomposition, in which the electric condition of the bodies concerned is not altered. Simple *change of form*, from solid to liquid, or from liquid to gaseous, is attended with electric disturbance; and this is greatly increased when any separation takes place between substances that were previously united, as when water containing a small quantity of saline matter is caused to evaporate and to leave it behind. *Heat*, again, is continually generating Electricity; for not only is a current produced by the heating of two dissimilar metals in contact, but also by the unequal heating of two parts of the same bar; and though the effect is most striking in the case of metals, it is by no means limited to them. And so constantly is Electricity generated by the retardation of *motion*, as in friction, that it is not possible to rub together any two substances, excepting such as are of the most perfect homogeneity (such as the fractured surfaces of a broken bar) without the production of electric change, as well as of heat.

precisely the same; and that the differences between them are greater in proportion to the diversity of the vital processes which are taking place in them, and to the activity with which these are being carried on. Thus, Donné found that the skin and most of the internal membranes are in opposite electrical states; and Matteucci observed a considerable deflection of the needle of a delicate galvanometer, when the liver and stomach of a rabbit were connected with its platinum electrodes.* More recently, Mr. Baxter has found that if one of the electrodes be placed upon any part of the intestinal surface, and the other be inserted into the branch of the mesenteric vein proceeding from it, a decided deflection of the needle was produced, indicating a positive condition of the blood; but that no effect was produced when the second electrode was inserted into the artery of the part, instead of into its vein. These effects were found to cease after the death of the animals; and could not be attributed, therefore, to mere chemical differences between the blood and the secreted product; but must have arisen from electric disturbance taking place in the very act of secretion.†—That the process of Nutrition, as well as of Secretion, in parts which are undergoing rapid molecular change, gives rise to electric disturbance, is proved by the experiments of Matteucci and Du Bois Reymond upon the relative electrical states of different parts of muscles and nerves. If the two extremities of a muscle, removed from the body of an animal very recently killed, be applied to the two electrodes of a delicate galvanometer, there is usually some deflection of the needle; this being greater in proportion to the difference in the arrangement of the muscular and tendinous elements at the two extremities. Although the direction of the current is constant for each muscle, yet there is no constant relation between the direction of the currents and the position of the muscles in the body; thus in the *gastrocnemius* of the Frog's leg, the direction is from the foot towards the body, whilst in the *sartorius* it is the reverse. Taking all the muscles of a part together, however, there is usually such a want of balance between the opposite currents, that a constant current is established in the direction of the strongest and most numerous of the separate muscular currents; this, in the Frog, passes uniformly from the hind-feet towards the head, and was at one time supposed to be peculiar to that animal; but a similar current may almost always be detected in other animals. The muscular current grows feebler and feebler, the longer the muscle has been removed from the body; it is affected by any agents which tend to lower its vitality, and becomes extinct as soon as its contractility ceases. From the experiments of M. du Bois-Reymond, to be presently described (§ 670), it may be concluded that the current in the arm of Man, when at rest, is from the shoulder towards the points of the fingers.

668. The conditions of the 'muscular current' have been made the subject of special investigation by M. du Bois-Reymond; and the following is an outline of the results at which he has arrived, for whose due comprehension, however, it is requisite that the terms employed by him should be first defined.—The entire muscle being composed of a mass of fibres, having a generally-parallel direction, and attached at their extre-

* See M. Becquerel's "Traité de l'Electricité," tom. i. p. 327, and tom. iv. p. 300.
† "Philosophical Transactions," 1848, p. 243.

mities to tendinous structure, which has in itself but little or no electro-motor power, but is a conductor of electricity, it follows that the tendon or tendinous portion of a muscle represents a surface formed by the *bases* of the muscular fibres considered as prisms, which may be designated its *natural transverse section.* On the other hand, the fleshy surface of the muscle, which is formed only by the *sides* of the fibres considered as prisms, may be regarded as the *natural longitudinal section* of the muscle. Again, if a muscle be divided in a direction more or less perpendicular to its fibres, an *artificial transverse section* will be made; whilst if the muscle be torn lengthways in the direction of its fibres, an *artificial longitudinal section* will be made; and these artificial sections show the same electric conditions with their corresponding natural sections. Now experiments repeated in a great variety of modes demonstrate that *every point in the natural or artificial longitudinal section of a muscle is positive in relation to every part of its transverse section, whether natural or artificial;* the most powerful influence on the galvanometer being produced, when a portion of the surface (or natural longitudinal section) of a muscle is laid upon one of the electrodes, and a portion of the surface formed by cutting the muscle across (or artificial transverse section) is placed against the other. When the two tendinous extremities of a muscle whose form is symmetrical or nearly so, are placed against the electrodes, the deflection of the needle of the galvanometer is but slight; and the same is the case with two transverse sections taken at equal distances from the two ends of the muscle, and also with two points of the longitudinal section which are equally distant from the middle of its length. But if the two points of the longitudinal section applied to the electrodes be not equally distant from the centre of the muscle, then the point which is nearest to the centre is positive to the one which is nearest to the end; and, in like manner, when the different parts of the transverse section are tested in regard to each other, the points lying nearest the surface of the muscle, are found to be positive to those nearer its interior. The intensity of the current, however, between any two points in the *same* section—whether transverse or longitudinal—is always incomparably less than that of the currents which are obtained between two points in *different* sections, one in the longitudinal and the other in the transverse. These results may be obtained, not merely with the entire muscle, but with insulated portions of it; and even, as we are assured by M. du Bois-Reymond, with a single primitive fasciculus. Hence it seems unquestionable, that every integral particle of the muscular substance must be a centre of electro-motor action, and must contain within itself positive and negative elements; and the variations both of intensity and direction in the muscular current, under certain circumstances, are so sudden and so extensive, that it appears impossible to account for them by any change of larger heterogeneous elements, or in any other way than by assuming corresponding changes of position in almost infinitely small centres of action. It is indifferent what form is assigned to these electromotive molecules; but it would seem that they must have two negative polar zones, and a positive equatorial zone; a combination of such elements being able to produce all the electrical effects of a muscle in a state of rest. It seems altogether best to suit the phenomena, to suppose that each of these *peripolar* molecules is formed by the combination of two

*dipolar* molecules, touching each other by their positive poles,—as in the subjoined table, which represents a band of four series, A, B, C, D, each series containing four dipolar molecules.

| | A | B | C | D | |
|---|---|---|---|---|---|
| 1 | —<br>+<br>+<br>— | —<br>+<br>+<br>— | —<br>+<br>+<br>— | —<br>+<br>+<br>— | 1 |
| 2 | —<br>+<br>+<br>— | —<br>+<br>+<br>— | —<br>+<br>+<br>— | —<br>+<br>+<br>— | 2 |
| 3 | —<br>+<br>+<br>— | —<br>+<br>+<br>— | —<br>+<br>+<br>— | —<br>+<br>+<br>— | 3 |
| 4 | —<br>+<br>+<br>— | —<br>+<br>+<br>— | —<br>+<br>+<br>— | —<br>+<br>+<br>— | 4 |

669. The current shown by the entire muscle, when made to form part of a circuit, is only a *derived* current produced by incomparably more intense currents circulating in the interior of the muscle around these ultimate particles, and will vary greatly in intensity, according to the mode in which these particles are arranged; generally speaking, however, it increases both with the length and with the thickness of the muscle. There is, however, another cause of a very remarkable nature, which influences both its intensity and its direction; this, according to M. du Bois-Reymond, is the existence of a thin layer of muscular substance, beneath the tendinous expansion, whose electromotive power is exactly opposite to that of the rest, so that its action tends to reverse the general law of the muscular current. For when the *gastrocnemius* of a frog is placed between the two electrodes, so as to touch them only with its tendinous extremities, it gives a weak upward current; but if the frog have been previously cooled, there will probably be no current at all; or if it have been frozen, there may actually be a current in the opposite direction. If, now, a drop of any liquid capable of corroding the muscular tissue (such as alcohol, creosote, acids, alkaline solutions, &c.) be placed upon the aponeurosis of the tendo Achillis, the ordinary upward current of the muscle is evolved; and the same effect is produced by completely removing a thin layer of muscular substance at the natural transverse section. This effect is accounted-for by M. du Bois-Reymond, on the supposition that at the tendinous extremities of the muscular fibres, the linear series of peripolar elements is terminated by a single dipolar element, whose positive pole is thus free, instead of the negative pole being so; and he has shown that by an apparatus of zinc and copper constructed after this plan, all the electric phenomena of the muscle at rest may be imitated.

670. That a change in the electric state of a muscle takes place in the act of contraction, had been ascertained by the experiments of Prof. Matteucci (§ 330); but as he was only able to detect this by the galvano-

scopic frog (the galvanometer which he employed not giving unquestionable indications of it), he was not able to determine its nature with accuracy. This has been accomplished, however, by M. du Bois-Reymond; who has shown that during contraction the muscular current is not increased (as supposed by Matteucci), but is diminished and even reduced to zero. In order to exhibit this phenomenon satisfactorily, it is found advantageous to cause the muscle to contract powerfully or uninterruptedly for as long a time as possible, that is, to *tetanize* it; and this may be effected by acting violently on its nerve by heat, chemical agents, or a succession of electric shocks; or by poisoning the animal with strychnia. In whatever mode the tetanized state is induced, the same result follows;—the needle of the galvanometer passes over to the negative side. This, however, does not indicate (as might be at first supposed) the development of a new current during the contraction, in a direction opposite to that which prevails during rest; but it is the consequence of the 'secondary polarity'* which is evolved in the platinum electrodes, as soon as the muscular current is diminished; the needle passing from the positive to the negative side, as soon as the current of the secondary polarity becomes more powerful than the original muscular current. This negative deflection of the needle at the moment of contraction, is always proportional to the actual intensity of the current of the muscle while at rest; and it ceases as soon as the tetanic contraction ceases, after which the muscular current gradually recovers its previous intensity.—Thus, then, it appears that the contraction of a muscle is attended with *a marked diminution of its electromotive power*; a fact which seems to harmonize well with the general views formerly adverted-to in regard to the 'correlation of forces;' the changes which operate to produce disturbance of electric equilibrium whilst the muscle is at rest, being concerned in the development of motor power when it is thrown into contraction. This alteration has been demonstrated by M. du Bois-Reymond in the living animal, after the following manner. The two feet of a live frog were immersed in the two connecting vessels, but one of the legs was paralysed by division of its sciatic plexus; the muscular currents of the muscles of the two limbs neutralized each other, so long as they remained at rest; but upon the frog being poisoned with strychnia, so that tetanic convulsions occurred in one limb whilst the other remained motionless, the current in the former limb was weakened, whilst that of the other remained unaffected, and a deflection of the needle took place, indicating an upward current in the paralyzed limb and a downward current in the tetanized one. The same thing may be shown in the Human subject, by dipping the forefingers of the two

* When the electromotor body is removed, and the two electrodes (platinum plates immersed in a saturated solution of common salt), are connected by some imperfectly conducting body, a secondary current is manifested in the reverse direction to the first, the needle being deflected to the other side; this is caused by the electro-chemical reaction of the substances which the current of animal electricity has evolved on the platinum plates by means of its electrolytic action; and its occurrence is often a useful and valuable confirmation of the first result, as showing that the primary deflection really was the consequence of the presence of an electromotor. When the electromotive action, moreover, is very weak, it may be made more evident by reversing the position of the electromotor, without first replacing the connecter; so that the action which it will then exert in the reverse direction, will be strengthened by the secondary current developed by the previous action.

hands into the two conducting vessels connected with the galvanometer, so that the two arms are included in opposite directions in the circuit; when if, after the needle (which usually undergoes a temporary disturbance on their first immersion) has come to a state of rest, all the muscles of one of the arms be strongly and permanently contracted, so as to give them the greatest possible tension without changing the position of the arm, the needle is instantly deflected, always indicating a current from the hand to the shoulder, that is, an *upward* current in the contracted arm. Hence, according to the explanation just given, the contracted arm plays the part of the negative metal in the circuit, in regard to the arm whose muscles remain in the state of relaxation, showing that the normal current will be a downward one.—This change, however, is so extremely slight, that a very delicate galvanometer is requisite to render it perceptible. Its intensity depends very much on the muscular energy of the experimenter; and even the greater power which the right arm usually possesses, becomes perceptible in the greater deflection of the needle when it is put in action.*

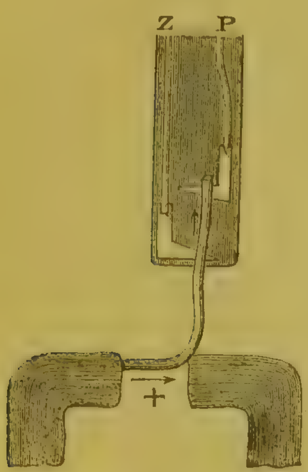
671. The discovery that an electric current exists in *nerves*, the conditions of which are in most respects similar to that of the Muscular current, is entirely due to M. du Bois-Reymond. When a small piece of a nerve-trunk is cut out from the recently-killed body, and is so placed upon the electrodes that it touches one of them with its surface (or natural *longitudinal* section), and the other with its cut extremity (or artificial *transverse* section), a considerable deflection of the index is produced, the direction of which always indicates the passage of a current from the interior to the exterior of the nerve-trunk. It is indifferent in regard to the direction of the current, whether the central or the peripheral cut extremity be applied to the electrode; and in fact the most powerful effect is obtained by doubling the nerve in the middle, and applying both transverse sections to one electrode, whilst the loop is applied to the other. On the other hand, if the two cut extremities be applied to the two electrodes respectively, no decided effect is produced; and the same neutrality exists between any two points of the surface of the trunk, equidistant from the middle of its length; but if the points be not equidistant, then a slight deflection is produced, indicating that the parts nearer the middle are positive to those nearer the extremities. It has not been found possible, owing to the small size of the nerve-trunks experimented-on, to test in a similar manner the relative state of different points of their transverse section; but there can be little doubt, from the complete conformity which exists in other respects between the nervous and muscular currents, that the same law will be found to prevail in this as in the former case; namely, that the points nearer the surface are

* Of this very remarkable experiment, which was first made by M. du Bois-Reymond, the Author has himself (through that gentleman's kindness) been a witness; and he gladly bears his testimony to its highly satisfactory character, and withdraws the doubt previously expressed (on the authority of Prof. Matteucci's negative statements) in regard to the reality of this phenomenon (§ 330, *note*).—The success of M. du Bois-Reymond in these and similar investigations, is doubtless due in great part to the marvellous sensitiveness of the galvanometer he employs, the coils of which consist of *three miles* of wire, as well as to the perfection of the various arrangements by which he is enabled to avoid or eliminate sources of error; but it must be attributed in great part also to the philosophic method on which his inquiries are planned, and to the skill and perseverance with which they are carried out.

positive to those nearer the centre. There is no difference between the motor and the sensory nerves in regard to the direction of this current, the existence of which has been proved by M. du Bois-Reymond, not only by the galvanometer, but also by the excitement of contractions in the limb of the galvanoscopic frog.—The 'nervous current,' like the muscular, must be considered as derived from the electromotive action of the molecules of the nerve; and, for the reasons already pointed out, the intensity of the current in the immediate neighbourhood of the molecules, may be infinitely greater than that which is shown by the galvanometer to exist in the trunk of the nerve.

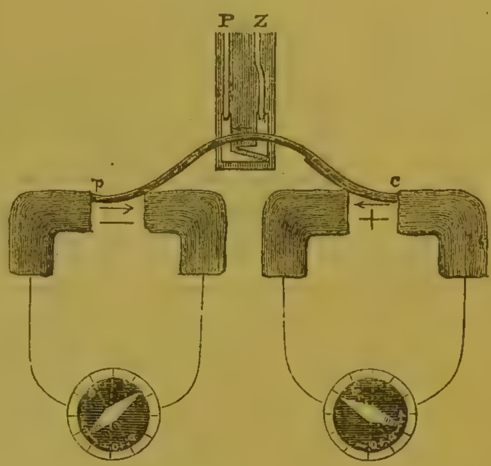
672. We have now to follow M. du Bois-Reymond through his investigations on the change in the condition of the 'nervous current,' whilst the nerve is in a state of functional activity, whether motorial or sensorial. For the examination of this, it is desirable to induce a state of continuous action in the nerve, analogous to the tetanic contraction of muscle; and this condition in the motor nerve, is manifestly that which induces tetanus in its muscle; whilst in sensory nerves it is that in which a violent sensation is uninterruptedly kept up. No means of exciting such a state are so certain and simple, as electric currents; but it is necessary in the first place to determine the modification which these currents may themselves produce in the proper 'nervous current.' If a portion of nerve-trunk be so placed (Fig. 126), that it touches one of the electrodes by its transverse section (which may be designated T), and the other by its surface or longitudinal section (L), and a portion of its continuation be included in a galvanic circuit, so that a current shall pass in the direction Z—P, which is *the same* in its direction as that between T—L, then the intensity of the 'nervous current' T—L, as indicated by the deflection of the needle of the galvanometer, will be found to undergo an increase; whilst on the other hand, if the electric current be passed in the contrary direction P—Z, the intensity of the 'nervous current' T—L will decrease.—The portion Z—P of the nerve, which is included in the electric circuit, is termed the *excited* portion, and the current passed through it is the *exciting current;* on the other hand, the portion T—L included between the electrodes of the galvanometer is the *derived* portion; and the altered condition of this part, which is produced by the extraneous current (this current having been experimentally proved by M. du Bois-Reymond to exert no direct influence on the galvanometer), is termed the *electrotonic state* of the nerve. When the intensity of the 'nervous current' is increased, the nerve is said to be in the *positive phase* of this electrotonic state; and when it is diminished, the nerve is in the *negative phase* of that state.—By a proper arrangement, the same exciting current may be made to produce the positive phase in one part of a nerve-trunk, and the negative phase in another. Thus if the two extremities of a nerve (Fig. 127, *p* and *c*), be so connected with two galvanometers, that both shall develope the 'nervous current,'

Fig. 126.



and an intermediate portion be excited by the transmission of an electric current in the direction Z—P, the nervous current in the 'derived' portion *c* will be increased in intensity, whilst that in the portion *p* will be diminished.—Hence it may be inferred that when any portion of the length of a nerve is traversed by an electric current, besides the usual electromotive action of the nerve, a new electro-motive action takes place in every point of the nerve, by a polarization of its electromotive elements, which action has the same direction as the exciting current itself; and a current is thus produced in the 'derived' portion, which is added to the original 'nervous current' at that end of the nerve at which the direction of this new current and of the nervous current coincide, and is subtracted at that end at which the directions are different. These variations in the intensity of the 'nervous current' continue as long as the 'exciting current' lasts, and immediately cease when the circuit of that current is broken. It is to the induction of the electrotonic state in the nerve supplying it, that the contraction of a muscle is due, which ensues on the completion of the circuit; and to the cessation of this state, that the muscular contraction is due which is consequent upon the interruption of the circuit. Hence the electrotonic changes in the condition of nerves may be observed without previous dividing them.—When, on the other hand, a nerve is 'tetanized' by passing an interrupted and alternating current through a portion of it, the effect is, as in the case of muscle, to produce a *diminution* in its own proper current; the needles of *both* galvanometers, in the arrangement last described, being deflected to the negative side, instead of one going back to zero, and the positive deflection of the other being increased, as happens when the 'excited portion' is subjected to a continuous and uniform current. The same negative variation of the nervous current has been demonstrated by M. du Bois-Reymond in nerves tetanized by other means, as by the use of strychnia. And the phenomena both of the 'electrotonic state,' and of the 'negative variation' are precisely the same, whether motor or sensory nerves be subjected to the experiment; thus making it appear that nerve-force may be transmitted in either direction along each of these orders of nerves.—A very remarkable modification of the 'nervous current' has been shown by M. du Bois-Reymond to follow severe injuries of the nerve, by mechanical, chemical, or thermal agencies. If, for instance, a piece of hot metal be brought near to the nerve without touching it, the nervous current will be seen to sink rapidly, and to have its direction reversed, during which the property possessed by the nerve of conveying irritation to the muscle, though somewhat impaired, will not be destroyed; and if, whilst in this abnormal state, the nerve be divided, every transverse section is found neutral or positive to the longitudinal section, instead of negative. If the nerve-trunk be then placed between muscles, so as to

FIG. 127.



recover its natural moisture, it will at the same time recover its usual electromotive power.*

673. Some of the most important parts of the body being thus in a state of constant *disequilibrium* with regard to each other, it is not surprising that the electric state of the whole should be ordinarily in disequilibrium with that of surrounding bodies. This difference, however, is usually prevented from manifesting itself, in consequence of the restoration of the equilibrium by the free contact which is continually taking place between them; and it is for the most part only when the Human body is insulated, that it becomes apparent. The galvanometer is then affected, however, by the contact of one of its electrodes with the person insulated, and the other with any neighbouring uninsulated body; and also by the contact of the electrode with the hands of two persons both insulated, who join their other hands together, a difference in the electrical states of the two individuals being thus indicated. The electricity of man is most frequently positive, and irritable men of sanguine temperament have more free electricity than those of phlegmatic character; the electricity of women is more frequently negative than that of men. There are persons who scarcely ever pull off articles of dress which have been worn next the skin, without sparks and a crackling noise being produced; especially in dry weather, when the electricity of the body is retained, instead of being rapidly dissipated as it is by a damp atmosphere. The effect is usually heightened, if silk stockings and other silken articles have been worn, since these act as insulators. It is doubtless in part attributable to the friction of the articles of dress against each other and against the body; but we can scarcely doubt that it is partly due to the generation of electricity in the body itself, since it bears no constant relation to the former of these supposed causes. Thus a Capuchin friar is mentioned by Dr. Schneider,† who, on removing his cowl, always found a number of shining crackling sparks to pass from his scalp; and this phenomenon continued still perceptible after a three weeks' illness. The most remarkable case of the generation of Electricity in the Human subject at present known, was recorded some years since in America.‡ The subject of it, a lady, was for many months in an electric state so different from that of surrounding bodies, that, whenever she was but slightly insulated by a carpet or other feebly conducting medium, sparks passed between her person and any object she approached; when most favourably circumstanced, four sparks per minute would pass from her finger to the brass ball of the stove at the distance of $1\frac{1}{2}$ inch. From

* The materials of the five preceding paragraphs have been derived from the sketch of M. du Bois-Reymond's researches, which has been recently published by Dr. Bence Jones ("On Animal Electricity; being an Abstract of the Discoveries of Emil du Bois-Reymond"). Having himself had the opportunity of witnessing a considerable number of the experiments above referred-to, the Author feels it due to M du Bois-Reymond to state, that their results corresponded so precisely with his predictions in every instance, as to prove that he had acquired a thorough mastery over the conditions of the phenomena. And he may mention the experimental demonstration of the 'nervous current,' as most fully satisfactory.—It may be stated with confidence, that the course of investigation which is being followed-out by M. du Bois-Reymond, is one pre-eminently calculated to develope results of importance in Physiology; and is the only one out of which definite indications in regard to the Therapeutic applications of Electricity can be expected to arise.

† "Casper's Wochenschrift," 1849, No. 15.

‡ "American Journal of Medical Sciences," January, 1838.

the pain which accompanied the passage of the sparks, her condition was a source of much discomfort to her. The circumstances which appeared most favourable to the generation of the electricity, were an atmosphere of about 80°, tranquillity of mind, and social enjoyment; whilst a low temperature and depressing emotions diminished it in a corresponding degree. The phenomenon was first noticed during the occurrence of an Aurora Borealis; and though its first appearance was sudden, its departure was gradual. Various experiments were made, with the view of ascertaining if the electricity was generated by the friction of articles of dress; but no change in these seemed to modify its intensity.

# CHAPTER XIV.

## OF THE FUNCTIONS OF THE NERVOUS SYSTEM.

### 1.—*General Summary.*

674. The Nervous System of Man, as of Vertebrated animals generally, consists of an aggregation of separate ganglionic centres, which are more or less intimately connected with each other by commissural fibres, and which are called into consentaneous activity in a large proportion of the operations of which this apparatus is the instrument. Hence, notwithstanding the abundant evidence that these several centres differ in their respective endowments, there is considerable difficulty in the determination of their special functions; since the destruction or removal of any one portion of the Nervous system not only puts a stop to the phenomena to which it is itself directly subservient, but so deranges the general train of nervous activity, that it often becomes impossible to ascertain, by any such method, what is its real share in the entire performance.—In this difficulty, however, we may advantageously have recourse to the study of the structure and actions of those forms of the Nervous system presented to us among the lower animals, in which its ganglionic centres are fewer and less intimately connected, and in which, therefore, it is more easy to gain an acquaintance with their several endowments. And from an extensive survey of these, we seem able to deduce the following conclusions, which afford the most valuable guidance in the study of the Nervous System of Man.*

I. The Nervous System, in its lowest and simplest form, may consist of but a single ganglionic centre,† with afferent and motor nerves (§ 350), whose function is essentially *internuncial;* impressions made upon the afferent fibres exciting respondent movements in the muscles supplied by the motor, without any necessary intervention of consciousness. Such movements are properly distinguished as *excito-motor*.

* For a general view of the facts on which these conclusions are based, see "Princ. of Phys., Gen. and Comp.," CHAP. XX.

† It may, perhaps, be doubted whether any Animal really exists, possessing such nervous system, and yet not endowed with consciousness. It is quite certain, however, that animals do exist (the Tunicated Mollusca for example), in which the actions above referred-to, are the only ones of which we have any distinct evidence from observation of their habits.

II. A repetition of such ganglionic centres may exist to any extent, without heterogeneousness of function, or any essential departure from the simple mode of action just indicated; each of these centres may be specially connected by afferent and motor fibres with one segment or division of the body, and may minister peculiarly to *its* actions; but the several centres may be so intimately connected by commissural fibres, that an impression made upon the afferent nerves of any one of them may excite respondent motions in other segments. This we see effected through the annular gangliated cord of the higher Radiata, and through the longitudinal gangliated cord of the Articulata; the disposition of the ganglia and of their connecting cords having reference simply to the general plan of the body.

III. A higher form of Nervous System is that in which the multiplication of ganglionic centres has reference, not to the multiplication of similar parts which are to be alike supplied with nervous power, but to the exercise of a diversity of functions, through the instrumentality of different structures; thus, in the higher Articulated and Molluscous tribes, we find ganglionic centres specially set apart for the actions of deglutition and respiration, as well as for those of locomotion; but the *modus operandi* is still the same, these actions being all 'excito-motor,' that is, being performed through the 'reflex' agency of their several ganglionic centres, without the necessary intervention of consciousness. These centres are connected with each other commissurally, when they are required to act with consentaneousness; and it is frequently to be observed in the most developed forms of each type, that they come into actual coalescence, their functional distinctness being still indicated, however, by the distribution of their nervous trunks.

IV. In all but the very lowest Invertebrata, the nervous system includes, in addition to the foregoing, certain ganglionic centres, situated in the neighbourhood of the entrance to the digestive cavity, and connected with certain organs, which, from their more or less close resemblance to our own instruments of special sense, we conclude to be organs of sight, smell, hearing, &c. Now as we know from our own experience, that impressions made upon these organs produce no further change unless we become *conscious* of them, and as the Invertebrata possess no distinct ganglionic centres of a higher character, it seems to be a legitimate inference that these 'sensorial' ganglia are the instruments by which the animals furnished with them are rendered cognizant of such impressions, and through which the sensations thus called into existence serve to prompt and direct their movements. What is commonly designated as the 'brain' of Invertebrata (more properly their 'cephalic ganglia') cannot be shown to consist of anything else than an assemblage of sensorial centres; and its actions appear to be entirely of a 'reflex' character, such of the movements of these animals as are not excito-motor, being performed (there is strong reason to believe) in respondence to sensations excited by internal or external impressions. Such movements, therefore, may be designated as *sensori-motor*, or *consensual*. Like the preceding, they must be accounted purely 'automatic,' since neither emotion, reason, nor will has any participation in them; and the proportion which they bear to the actions of the excito-motor kind, seems to correspond pretty closely with the relative development of the cephalic ganglia and of the rest of the

nervous system, as is very obvious when the larva and imago states of Insects are compared.—However disjoined the various excito-motor centres may be amongst each other, we uniformly find them connected with the cephalic ganglia by commissural tracts; and this anatomical fact, with many phenomena which observation and experiment upon their actions have brought to light, makes it apparent, that besides the reflex actions which are performed through their own direct instrumentality, the sensory ganglia have a participation in those performed through other ganglionic centres. Thus it seems probable that a stimulus transmitted downwards from the sensory ganglia, to one of the ganglia of the trunk of a Centipede, excites the efferent nerves of that ganglion to call into contraction the muscles supplied by them, just as the excitor influence arriving at that ganglion through its own afferent nerve would do.

675. The whole Nervous System of Invertebrated animals, then, may be regarded as ministering entirely to *automatic* action; and its highest development, as in the class of Insects, is coincident with the highest manifestations of the 'instinctive' powers, which, when carefully examined, are found to consist entirely in movements of the excito-motor and sensori-motor kinds. When we attentively consider the habits of these animals, we find that their actions, though evidently adapted to the attainment of certain ends, are very far from evincing a *designed* adaptation on the part of the beings that perform them, such as that of which we are ourselves conscious in our own voluntary movements, or which we trace in the operations of the more intelligent Vertebrata. For, in the first place, these actions are invariably performed in the same manner by all the individuals of a species, when the conditions are the same; and thus are obviously to be attributed rather to a uniform impulse, than to a free choice; the most remarkable examples of this being furnished by the economy of Bees, Wasps, and other 'social' Insects, in which every individual of the community performs its appropriate part, with the exactitude and method of a perfect machine. The very perfection of the adaptation, again, is often of itself a sufficient evidence of the unreasoning character of the beings which perform the work; for, if we attribute it to their own intelligence, we must admit that this intelligence frequently equals, if it does not surpass, that of the most accomplished Human reasoner.*

* Of this we have a most remarkable example in the architecture of the common Hive-Bee.—The *hexagonal* form of the cell is the one in which the greatest strength, and the nearest approach to the cylindrical cavity required for containing the larva, are attained, with the least expenditure of material. But the instinct which directs the Bees in the construction of the partition that forms the bottom or end of the cell, is of a nature still more wonderful than that which governs its general shape. The bottom of each cell rests upon three partitions of cells upon the opposite side of the comb; so that it is rendered much stronger, than if it merely separated the cavities of two cells opposed to one another. The partition is not a single plane surface; but is formed by the union of three rhomboidal planes, uniting in the centre of each cell. The angles formed by the sides of these rhombs, were determined by the measurements of Maraldi to be 109° 28′ and 70° 32′; and these have been shown, by mathematical calculation, to be *precisely* the angles, at which the greatest strength and capacity can be attained, with the least expenditure of wax. The solution of the problem was first attempted by Kœnig, a pupil of the celebrated Bernouilli; and as his result proved to differ from the observed angle by only two minutes of a degree, it was presumed that the discrepancy was due to an error of observation, which it was easy to account for by the smallness of the surfaces whose inclination had to be measured. The question has been since taken up, however, by Lord Brougham (Appendix to his Illustrated edition of "Paley's

Moreover, these operations are performed without any guidance from experience; for it can be proved in many cases, that it is impossible for the beings which execute them to have received any instruction from their parents; and we see that they do not themselves make any progressive attempts towards perfection, but accomplish their work as well when they first apply themselves to it, as after any number of repetitions of the same acts. It is interesting to observe, moreover, that as these instinctive operations vary at different periods of life, so is there a corresponding variation in the structure of the Nervous system. Thus we see that, in the *larva* of the Insect, these operations are entirely directed towards the acquisition of food; and its organs of sense and locomotive powers are only so far developed as to serve this purpose. But in the *imago* or perfect Insect, the primary object is the continuance of the race; and the sensorial and motor endowments are adapted to enable the individual to seek its mate, and to make preparations (frequently of a most elaborate kind) for the nurture of the offspring. Hence we can scarcely fail to arrive at the conclusion, that the *adaptiveness* of the instinctive operations of Insects, &c., lies in the original construction of their nervous system, which causes particular movements to be executed in direct respondence to certain impressions and sensations. And this view is confirmed by the comparison of these movements with those which have been always recognized as 'instinctive' in the Human being; thus, the act of sucking in the infant requires the combined exertion of a considerable number of muscles, which combination is clearly not the result of intelligence and will, but is a purely 'reflex' act (§ 423); and the same may be said of the acts of coughing and sneezing (§ 555), the *purpose* of which is most obvious, and the adaptation to that purpose most complete, yet these acts are most assuredly *not* performed with any notion of their purpose, but at the prompting of an irresistible impulse, which, originating in an excitation applied to a sensory surface and conveyed to the automatic centres, becomes the immediate source of all the separate muscular contractions which combine to accomplish the pre-arranged result.*

676. Thus, then, the type of psychical perfection among Invertebrated animals, which is manifested in the highest degree in the Social Insects, consists in the exclusive development of the *Automatic* powers; in virtue of which, each individual performs those actions to which it is directly

Natural Theology"); who has worked it out afresh, and has shown that, when certain small quantities, neglected by Kœnig, are properly introduced into the calculation, the result is exactly accordant with observation,—the *Bees* being thus proved to be *right*, and the *Mathematician wrong*.

* We have not, perhaps, any right to affirm that there is *nothing whatever* analogous in the Invertebrata to the Reasoning powers and Will of higher animals; but if these faculties have any existence among them, they must be regarded as in a merely rudimentary state, corresponding with the undeveloped condition of the Cerebrum. In none of the Articulata has any trace of this organ been discovered; a rudiment of it, however, has been supposed to exist in the Cuttle-fish. The only distinct indication of intelligence displayed by Invertebrata, is the slight degree of capacity of "learning by experience" which some of them display; this capacity being limited to the mere formation of *associations* between the mental states called up by different objects of sense, which we observe to be the first stage in the development of the mental powers in the Human infant. And it is interesting to remark that this educability is less displayed by Insects, in which we may consider the Automatic tendencies as attaining their highest development, than it is in Spiders, which present in several points of their conformation an approximation towards the Vertebrated series.

prompted by the impulses arising out of impressions made upon its afferent nerves, without any self-control or self-direction; so that it must be regarded as entirely a creature of necessity, performing its instrumental part in the economy of Nature from no design or will of its own, but in accordance with the plan originally devised by its Creator. On turning to the Vertebrated series, on the other hand, we find that perfection consists in the highest development of the *Intelligence*, and in the supreme domination of the *Will*, to which all the automatic movements, save those which are absolutely essential to the maintenance of the organic functions, are brought under subjection; so that each individual becomes an independent, self-moving, and self-controlling agent, all whose actions are performed with a definite purpose which is distinctly before his own view, and are adapted to the attainment of their end by his own reason. This, however, is only true of Man in his highest state of psychical development; for not only do the actions of the lower Vertebrata appear to be nearly as much under the direction of automatic impulses as are those of the Invertebrated classes, but the same is true of those of the Human species in infancy and early childhood; and a very close correspondence may be traced, between the gradual development of the Intelligence, and the progressive acquirement of Volitional dominance, in the ascending series of Vertebrated animals, and in the advance of Man from the mental state of childhood (which is permanently retained, as to all its essential characters, in many adults, and even in whole races of the least cultivated order) to the highest elevation which his nature is capable of displaying, in his present sphere of existence.—The super-addition of these more elevated psychical endowments is coincident with the addition of a peculiar ganglionic centre, the Cerebrum, to the automatic apparatus of Vertebrated animals; and the relative proportion which this bears to the automatic centres, both as to size and complexity of structure, corresponds so closely with the degree of predominance which the Intelligence and Will possess over the Instinctive propensities, that it is scarcely possible to doubt that the Cerebrum is the instrument through which these higher psychical powers are exercised. Even in Man, however, the Automatic division of the Nervous system still constitutes its fundamental and essential part; for not only is it the instrument of all those actions which are directly excited by sensations or impressions derived from without, many of these being necessary to the maintenance of his organic functions; but it is also the connecting link between the Cerebrum and the external world. For, as will appear hereafter, the Cerebrum receives all its stimulus to action through the sensorial ganglia, to which all the proper sensory nerves are traceable; whilst, on the other hand, in carrying into effect the mandates of the will, it does not operate directly upon the muscles, but affects them through the instrumentality of the Automatic motor apparatus.

677. The dominant character of the Nervous System in Vertebrated animals, is marked by the subserviency of the whole organism to its purposes. In a large proportion of the Invertebrata, the Nervous system seems like an appendage to the rest of the structure, a mechanism superadded for the sake of bringing its various parts into more advantageous relation; and we do not find any special adaptation of the organs of support for its protection. But in all the Vertebrated classes, we

find that the internal osseous skeleton, whose existence supplies the most distinctive character of the group, is adapted not merely to furnish the most complete and efficient protection to the Nervous centres, but also to afford points of attachment to the Muscles, as well as a system of inflexible levers on which they may exert the contractile power called forth by the nerves; so that the development of the neuro-skeleton (thus designated in contradiction to the dermo-skeleton) has a constant relation to that of the Nervo-muscular apparatus. This is most remarkably seen in Man; in whom the 'archetype' or fundamental plan of the Vertebral skeleton is most departed-from, in order that it may be adapted to his special requirements.* And it is in him, too, that the Nervous system presents the greatest proportionate development, and that, by the intimate connections which subsist between its several parts, it is made so far to constitute *one whole*, that the determination of their respective functions is attended with the greatest difficulty. It has been, in fact, through the too exclusive attention commonly paid to Human Anatomy, that the meaning of the facts brought to light by dissection has been very commonly misapprehended; and that many of the physiological interpretations based upon them, have been completely negatived by more extended inquiry.—It is only, in fact, by studying the Cerebro-Spinal apparatus in its lowest, as well as in its highest form, and by bringing the intervening grades into comparison with both extremes, that it is possible to establish what are its fundamental or essential, and what its accessory parts; and in this way only can such a correspondence be established between the development of a particular structure, and the manifestation of a certain psychical endowment, as may enable the latter to be attributed with any degree of probability to the former. In fact, there is no part of the Human Organism, as to which the advantages of such a comparison are so striking, or in which the value of the "experiments ready prepared for us by Nature" is so much above that of the results of artificial mutilations.

678. Under the guidance, then, of these principles, we find that we may distinguish, as the fundamental part of the Nervous system of Man, the *Cranio-Spinal Axis*, consisting of the Spinal Cord, the Medulla Oblongata, and the Sensory Ganglia, and altogether constituting the centre of automatic movement.—The Spinal Cord, consisting of a tract of vesicular matter enclosed within strands of longitudinal fibres, and giving-off successive pairs of intervertebral nerves which are connected at their roots with both of these components, is obviously homologous with the gangliated ventral column of the Articulata, differing from it only in the continuity of the ganglionic substance which occupies its interior; and each segmental division of it, which serves as the centre for its own pair of nerves, may be considered, like each ganglion of the ventral column of the Articulata, as a repetition of the single 'pedal' or locomotive ganglion of the Mollusca.—The Medulla Oblongata consists of a set of strands, which essentially correspond with the cords that pass round the œsophagus in Invertebrated animals, connecting the cephalic ganglia with the first sub-œsophageal ganglion; but as the whole cranio-spinal axis in the Vertebrata lies *above* the alimentary canal (the trunk

* See "Princ. of Phys., Gen. and Comp.," § 326 *k*.

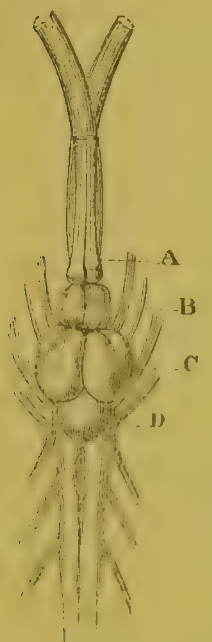
being supposed to be in a horizontal position), there is no such divergence of these strands, the only separation between them being that which is known as the 'fourth ventricle.' Interposed among the commissural fibres of the Medulla Oblongata, however, are certain collections of vesicular matter, which serve as the ganglionic centres for the movements of respiration and deglutition, and which thus correspond with the respiratory and stomato-gastric ganglia of Invertebrated animals. This incorporation of so many distinct centres into one system, would seem destined in part to afford to all of them the protection of the vertebral column; and in part to secure that consentaneousness of action and that ready means of mutual influence, which are peculiarly requisite in beings in whom the activity of the Nervous system is so predominant. Thus the close connection which is established in the higher Vertebrated animals, between the respiratory and the general locomotive apparatus, is obviously subservient to the use which the former makes of the latter in the performance of its functions; whilst, on the other hand, the control which their encephalic centres possess over the actions of the respiratory ganglia, enables the will to regulate the inspiratory and expiratory movements, in the manner required for the acts of vocalization. — Under the term Sensory Ganglia may be comprehended that assemblage of ganglionic masses lying along the base of the skull in Man, and partly included in the Medulla Oblongata, in which the nerves of the 'special senses,' Taste, Hearing, Sight, and Smell, have their central terminations; and with these may probably be associated the two pairs of ganglionic bodies known as the Corpora Striata and Thalami Optici, into which may be traced the greater proportion of the fibres that constitute the various strands of the Medulla Oblongata, and which seem to stand in the same kind of relation to the nerves of Touch or 'common sensation,' that the Olfactive, Optic, Auditory, and Gustative ganglia bear to their several nerve-trunks.

679. Now it is not a little interesting, that this Cranio-Spinal axis, which represents in Vertebrated animals the whole nervous system of the Invertebrata (with the exception of the rudiment of the Sympathetic which they possess), should exist in the lowest known Vertebrated animal without any superaddition, and should be sufficient for the performance of all its actions. Such is the case in the curious *Amphioxus*,* which presents not the slightest trace of either Cerebrum or Cerebellum, and in which even the sensory ganglia and the organs of special sense have only a rudimentary existence; and, in which, too, the spinal cord is composed of a series of ganglia that are obviously distinct from each other, although in close approximation. And even in the lower Cyclostome Fishes, the condition of the nervous centres is very little above this, save as regards the larger development of the sensory ganglia. This condition has its parallel, even in the Human species, in the case of Infants which are occasionally born without either Cerebrum or Cerebellum; such have existed for several hours or even days, breathing, sucking, crying, and performing various other movements; and there is no physiological reason why their lives should not be prolonged, if they be nurtured with sufficient care (§ 373).

* "Princ. of Phys., Gen. and Comp.," § 321.

680. In Man, however, as in all the higher Vertebrata, we find superimposed (as it were) upon the Sensory ganglia, and constituting the principal mass of the Encephalon, the bodies which are known as the *Cerebral Hemispheres*, or *Hemispheric Ganglia*. Now when these are so greatly developed as to cover-in and obscure the Sensory ganglia to the degree which presents itself in Man, it is not surprising that the fundamental importance of the latter should not be generally recognized; in Fishes, however, the proportion between the two sets of centres is entirely reversed, the rudiments of the Cerebral Hemispheres (Fig. 128, B) being usually inferior in size to the Optic ganglia (C) alone. Indeed, of the pair of ganglionic masses to which that designation is usually applied, it may be almost positively stated that the greater part is homologous with the Corpora Striata of the Human brain; it being only in the higher Cartilaginous fishes that a ventricular cavity exists in each of these bodies, separating the thin layer of true Cerebral substance which overlies it, from the ganglionic mass which forms its floor. Between these two extremes, a regular gradation is presented in the intermediate tribes.—Now it is a point especially worthy of note, that no sensory nerves terminate directly in the Cerebrum, nor do any motor nerves issue from it; and there seems a strong probability that there is not, as formerly supposed, a direct continuity between any or all of the nerve-fibres distributed to the body, and the medullary substance of the Cerebrum. For whilst the nerves of 'special' sense have their own ganglionic centres, it cannot be shown that the nervous fibres of 'general' sense which either enter the cranium as part of the cephalic nerves, or which pass up from the Spinal cord, have any higher destination than the Thalami Optici. So the motor fibres which pass forth from the cranium either into the cephalic nerve-trunks or into the motor columns of the Spinal cord, cannot be certainly said to have a higher origin than the Corpora Striata. And we shall find strong physiological ground for the belief, that the Cerebrum has no communication with the external world, otherwise than by the Sensori-motor apparatus which ministers to the automatic actions; and that even the movements which are usually designated as 'voluntary' are only so as regards their original source, the power which calls the muscles into contraction being even then immediately derived from the Cranio-Spinal axis, as it is in the purely automatic movements excited by an external impression.

FIG. 128.




Brain of *Cod*;—A, olfactive ganglia; B, cerebral lobes; C, optic ganglia; D, cerebellum.

681. Wherever a Cerebrum is superimposed upon the Sensory Ganglia, we find another ganglionic mass, the *Cerebellum*, superimposed upon the Medulla Oblongata. The development of this organ bears a general, but by no means a constant relation to that of the Cerebrum; for in the lowest Fishes it is a thin lamina of nervous matter on the median line, only partially covering-in the 'fourth ventricle;' whilst in the higher Mammalia, as in Man, it is a mass of considerable size, having two lateral

lobes or hemispheres in addition to its central portion. The direct communication which the Cerebellum has with both columns of the Spinal Cord, and the comparatively slight commissural connection which it possesses with the higher portions of the Encephalic centres, justify the supposition that it is rather concerned in the regulation and co-ordination of the actions of the former, than in any proper psychical operations; and it will hereafter be shown that the evidence afforded by Comparative Anatomy, by Experimental inquiry, and by Pathological observation, all tends to support this view of its function.

682. Now although every segment of the Spinal Cord and every one of the Sensory Ganglia, may be considered, in common with the Cerebrum, as a true and independent centre of nervous power, yet this independence is only manifested when these organs are separated from each other, either structurally—by actual division, or functionally—by the suspension of the activity of other parts. In their state of perfect integrity and complete functional activity, they are all (at least in Man) in such subordination to the Cerebrum, that they only minister to *its* actions, except in so far as they are subservient to the maintenance of the organic functions, as in the automatic acts of breathing and swallowing. With regard to every other action, the Will, if it possess its due predominance, can exercise a determining power; keeping in check every automatic impulse, and even repressing the promptings of emotional excitement. And this seems to result from the peculiar arrangement of the nervous apparatus; which causes the excitor *impression* to travel in the *upward* direction, if it meet with no interruption, until it reaches the Cerebrum, without exciting any reflex movements in its course. When it arrives at the Sensorium, it makes an impression on the consciousness of the individual, and thus gives rise to a *sensation;* and the change thus induced, being further propagated from the sensory ganglia to the Cerebrum, becomes the occasion of the formation of an *idea.* If with this idea any pleasurable or painful feeling should be associated, it assumes the character of an *emotion;* and either as a simple or as an emotional idea, it becomes the subject of *intellectual operations,* whose final issue is in a *volitional determination,* or act of the Will, which may be exerted in producing or checking a muscular movement, or in controlling or directing the current of thought.

683. But if this ordinary upward course be anywhere interrupted, the impression will then exert its power in a *transverse* direction, and a 'reflex' action will be the result, the nature of this being dependent upon the part of the Cerebro-Spinal axis at which its ascent had been checked. Thus if the interruption be produced by division or injury of the Spinal Cord, so that its lower part is cut-off from communication with the encephalic centres, this portion then acts as an independent centre, and impressions made upon it through the afferent nerves proceeding to it from the lower extremities, excite violent reflex movements, which, being thus produced without sensation, are designated as 'excito-motor.'—So, again, if the impression should be conveyed to the Sensorium, but should be prevented by the removal of the Cerebrum, or by its state of functional inaction, or by the direction of its activity into some other channel, from calling forth ideas through its instrumentality, they may react upon the motor apparatus by the 'reflex' power of the Sensory ganglia themselves;

as seems to be the case with regard to those locomotive actions which are maintained and guided by sensations during states of profound abstraction, when the attention of the individual is so completely concentrated upon his own train of thought, that he does not *perceive* external objects, although his movements are obviously guided through the visual and tactile senses. Such actions, being dependent upon the prompting of sensations, are 'sensori-motor' or 'consensual.'—But further, there is evidence that even the Cerebrum may respond (as it were) automatically to impressions fitted to excite it to 'reflex' action, when from any cause the Will is in abeyance, and its power cannot be exerted either over the muscular system or over the direction of the thoughts. Thus in the states of Dreaming, Somnambulism, and even Reverie, whether spontaneous or artificially induced (Sect. 7), *ideas* which take possession of the mind, and from which it cannot free itself, may excite respondent movements; and this may happen also when the force of the idea is morbidly exaggerated, and the will is not suspended but merely weakened, as in many forms of Insanity. With these ideas, moreover, Emotional states may be mixed-up, and even Intellectual processes may be prompted by them; so long, however, as these psychical operations take place at the mere *suggestion* of antecedent impressions (the particular changes which these suggestions excite being determined by the mental constitution and habits of thought of the individual), so long must the actions proceeding from them be considered as manifestations of the 'reflex' power of the Cerebrum, and consequently as no less automatic in their character, than are those which result from the reflex power of the Cranio-Spinal axis. Those actions which proceed from simple ideas, without any excitement of feeling, may be designated as *ideo-motor;* whilst those which spring from a passion or emotion may be termed *emotional.* The automatic nature of the purely emotional actions can scarcely be denied; when the passions are strongly excited, their impulses even acquire the mastery over the strongest exertion of the Will; and it is in individuals in whom the habitual control of the Will is the weakest, that we observe the emotions to act most powerfully on the bodily frame.

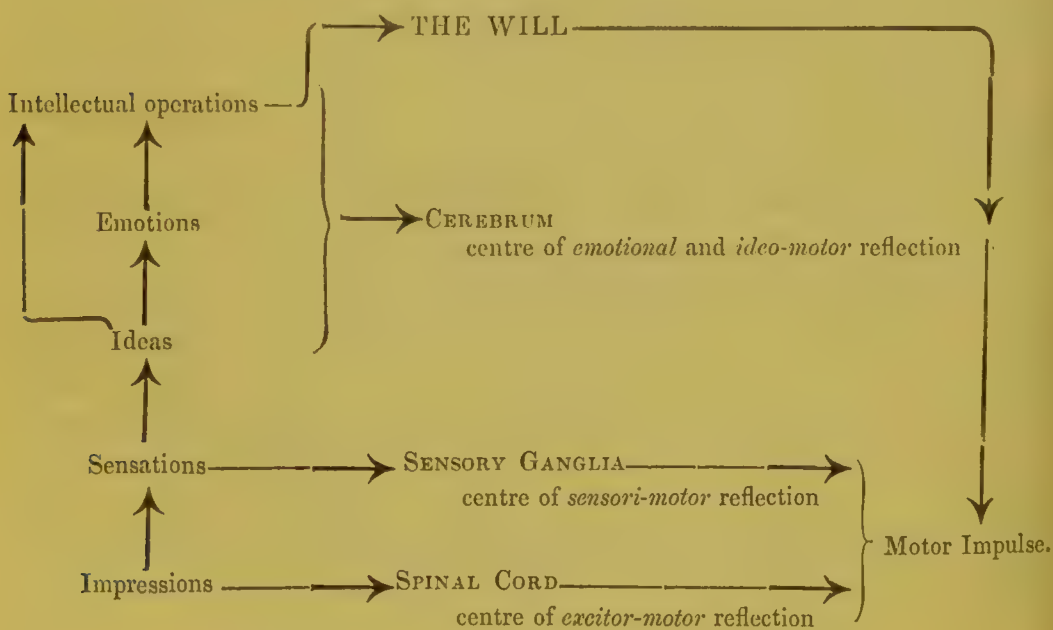
684. The dominant power of the Will, not only over every act of the nervo-muscular apparatus which is not immediately concerned in the maintenance of the vital functions, but over the course of purely psychical action, is probably the most distinctive attribute of the Human mind in its highest phase of development; and it is that which gives to each individual the freedom of action, which every one is conscious to himself that he is capable of exerting. Notwithstanding the evidences of rationality which many of the lower animals present, and the manifestations which they display of emotions that are similar to our own, there is no ground to believe that they have any of that controlling power over their psychical operations which *we* possess; on the contrary, all observation seems to lead to the conclusion, that they are under the complete domination of the ideas and emotions by which they are for the time possessed, and have no power either of repressing these by a forcible act of Will, or of turning the attention, by a like voluntary effort, into another channel. In this respect, then, their condition resembles that of the dreamer, the somnambule, or the insane patient, in all of whom this voluntary control is suspended, and who (when their minds are suscept-

ible of external impressions) may be so 'played-upon' by the suggestion of ideas, that any respondent action consistent with the habitual mental state of the individual, may be evoked by an appropriate stimulus; just as we see in the case of animals that are trained to the performance of particular sets of movements, which are executed in respondence to certain promptings conveyed to them through their sensorium. Now between the complete want of this controlling power of the Will, and the most perfect possession of it, every intermediate gradation is presented by the several individuals which make up the Human species; some persons being so much accustomed, in consequence of the weakness of their Will, to act directly upon intellectual or emotional suggestions, that they can scarcely be said to be voluntary agents; and others allowing certain dominant ideas or habitual feelings to gain such a mastery over them, as to exercise that determining power which the Will alone ought to exert. This gradation may be perfectly traced in children, in whose education the development of the faculty of 'self-control' should be a leading object; and it is also displayed in some of those phases of mental Imbecility, which result from a deficiency of the power of fixing the attention upon any object of consciousness, and of withdrawing it from external objects that tend to distract the mind by suggesting new ideas and trains of thought. On this power of self-direction, indeed, all the higher developments of intellectual power almost essentially depend; and we shall hereafter see how largely it is concerned in that progressive exaltation of the Moral nature, which, even more than Intellectual capacity, tends to bring the Human soul into relation with its Creator.

685. This directing power of the Will seems to be most strongly exerted, however, over those actions which are most closely connected with *psychical* changes, and which are exclusively *Cerebral* in their seat. It has been already pointed-out, that the Cranio-spinal axis not merely serves as the channel for the reception of the impressions which excite the activity of the Hemispheric ganglia, and as the instrument whereby the results of their operation are brought to bear upon the muscular system; but that it is also the centre of reflexion through which various automatic movements are called forth, that are immediately concerned in the maintenance of the organic functions. The impressions which excite these movements, do not in general pass-on to the Cerebrum; for we only perceive them when we specially direct our attention to them, or when they exist in unusual potency. Thus we are unconscious of the 'besoin de respirer' by which our ordinary movements of respiration are prompted; and it is only when we have refrained from breathing for a few seconds, that we experience a sensation of uneasiness which impels us to make forcible efforts for its relief. Notwithstanding, however, that the Cerebrum is thus unconcerned in the ordinary performance of these automatic movements, yet it can exert a certain degree of control over many of them, so as even to suspend them for a time; but in no instance can it carry this suspension to such an extent, as seriously to disarrange the organic functions; thus, when we have voluntarily refrained from breathing for a few seconds, the inspiratory impulse so rapidly increases in strength with the continuance of the suspension, that it at last overcomes the most powerful effort we can make for the repression of the movements to which it prompts. Now in this and similar cases, it would

seem as if the Will interfered to prevent that direct transverse passage of the stimulus from the afferent to the efferent nerves, through the Cranio-Spinal axis, which constitutes the ordinary line of action for impressions having their origin in the necessities of the organic or vegetative life of the individual. That the Will should have a certain degree of control over these movements, is necessary in order that they may be rendered subservient to various actions which are necessary for the due exercise of Man's psychical powers; but that they should not be left dependent upon its exercise, and should even be executed in opposition to it, when the wants of the system imperatively demand their performance, constitutes a wise provision for securing Life against the chances of inattention or momentary caprice.

686. The general views here put forth in regard to the independent and connected actions of the several primary divisions of the Cerebro-Spinal apparatus, may perhaps be rendered more intelligible by the following Table, which is intended to represent the ordinary course of operation when the whole is in a state of complete functional activity (§ 682), and the character of the 'reflex' actions to which each part is subservient, when it is the highest centre that the impression can reach (§ 683).




687. Having thus considered the principal attributes of the ganglionic centres of the Cerebro-Spinal system, we have next to inquire into those of the nerve-trunks which are connected with them.—It is only in the Vertebrata, that the difference between the *afferent* and *efferent* fibres of the nerves, has been satisfactorily determined. The merit of this discovery is almost entirely due to Sir C. Bell, who was led to it by a chain of reasoning of a highly philosophical character; and although his first experiments on the Spinal nerves were not satisfactory, he virtually determined the respective functions of their two roots, by experiments and pathological observations upon the cranial nerves, some of which contain only one class of fibres to the exclusion of the other, before any other

physiologist came into the field.* Subsequently his general views were confirmed by the very decided experiments of Müller; but until very recently, some obscurity hung over a portion of the phenomena. It was from the first maintained by Magendie, and has been subsequently asserted by other physiologists, that the anterior and posterior roots of the nerves were *both* concerned in the reception of impressions and in the production of motions; for that, when the anterior roots were touched, the animal gave signs of pain, at the same time that convulsive movements were performed: and that, on touching the posterior roots, not only the sensibility of the animal seemed to be affected, but muscular motions were excited. These physiologists were not willing, therefore, to admit more, than that the anterior roots were *especially* motor, and the posterior *especially* sensory. But the knowledge we now possess of the reflex function of the Spinal Cord, enables the latter portion of these phenomena to be easily explained. The motions excited by irritating the posterior roots are found to be entirely dependent upon their connection with the Spinal Cord, and upon the integrity of the anterior roots and of the trunks into which they enter; whilst they are not checked by the separation of the posterior roots from the peripheral portion of the trunk: it is evident, therefore, that excitation of the posterior roots does not act immediately upon the muscles through the trunk of the nerve, which they contribute to form; but that it excites a motor impulse in the Spinal Cord, which is propagated through the anterior roots to the periphery of the system. The converse phenomenon, the apparent sensibility of the anterior roots, has been explained by the experiments of Dr. Kronenberg,† which seem to prove, that it is dependent upon a branch from the posterior roots passing into the anterior roots at their point of inosculation, and then directing itself towards the cord (§ 692).

688. Every fibre, there is reason to believe, runs a distinct course between the central organ, in which it loses itself at one extremity, and the muscle or organ of sense in which it terminates at the other. Each nervous trunk is made up of several fasciculi of these fibres; and each fasciculus is composed of a large number of the ultimate fibres themselves. Although the fasciculi occasionally intermix and exchange fibres with one another (as occurs in what is termed a *plexus*), the fibres themselves never inosculate. Each fibre would seem, therefore, to have its appropriate office, which it cannot share with another.—Several objects appear to be attained by the plexiform arrangement. In some instances it serves to intermix fibres, which have endowments fundamentally different; for example, the Spinal Accessory nerve, at its origin, appears to be exclusively motor, and the roots of the Pneumogastric to be as exclusively afferent; but by the early admixture of these, a large number of motor fibres are imparted to the Pneumogastric, and are distributed in variable proportion, with its different branches; whilst few of its sensory filaments seem to enter the Spinal Accessory.—In other instances, the object of a plexus appears to be, to give a more advantageous distribution to fibres, which all possess corresponding endowments. Thus the brachial plexus mixes together the fibres arising from five segments of the spinal cord, and sends off five

* See "Brit. and Foreign Med. Review," vol. ix. p. 140, &c.

† "Müller's Archiv.," 1839, Heft v.; and "Brit. and For. Med. Rev.," vol. ix. p. 547.

principal trunks to supply the arm. Now if each of these trunks had arisen by itself, from a distinct segment of the spinal cord, so that the parts on which it is distributed had only a single connection with the nervous centres, they would have been much more liable to paralysis than at present. By means of the plexus, every part is supplied with fibres arising from each segment of the spinal cord; and the functions of the whole must therefore be suspended, before complete paralysis of any part can occur from a cause which operates above the plexus. Such a view is borne out by direct experiment; for it has been ascertained by Panizza that, in Frogs, whose crural plexus is much less complicated than that of Mammalia, section of the roots of one of the three nerves which enter into it, produces little effect on the general movements of the limb; and that, even when two are divided, there is no paralysis of any of its actions, all being weakened in a nearly similar degree.—But as Dr. Gull has pointed out,* one use of such a plexus as the brachial or the crural appears to be, to bring the muscles which derive their nervous supply from it, into relation with different ganglionic segments of the Spinal Cord; each of which may exert a diverse action, either in virtue of its own endowments, or of the influence of the will upon it; so that groups of muscles may thus be associated for combined actions. All consideration of the mode in which we make use of our muscles, and of the power which we have over them, leads to the conclusion that each ganglionic centre has a specific and limited sphere of influence, producing certain movements and no others; hence for the execution of a variety of movements in harmonious combination with each other, it seems requisite that the nervous supply of each muscle should be derived from several different centres; and thus it is that the complication of plexuses comes to be related to the variety of movements of the parts supplied through them.—It is not a little interesting to remark, that arrangements of a similar kind should present themselves among the higher Invertebrata. Thus, in Hymenopterous Insects (as first pointed out by Mr. Newport), there is a plexiform interlacement between the nerves of the anterior and of the posterior pairs of wings, which act very powerfully together; whilst in the Coleoptera, in which the anterior wings are converted into elytra, and are motionless during flight, the nerves supplying each pair run their course distinctly. In the Octopus, or Poulp, again, the trunks which radiate from the cephalic mass to the eight large arms surrounding the head, are connected by a circular band, forming a kind of plexus, which seems to contribute to the very powerful and harmonious movements of the arms of this Cephalopod.

689. The following statements, in which the doctrines of Prof. Müller† are adopted with some modifications and additions, embody the general principles ascertained by experiment, respecting the transmission of sensory and motor impressions along the nerves which respectively minister to them. Their *rationale* will be at once understood, from the facts already mentioned in regard to the isolated character of each fibril, and the identity of its endowments through its whole course.

I. When the whole trunk of a *sensory* nerve is irritated, a sensation is

* 'Gulstonian Lectures on the Nervous System,' in "Medical Times," 1849, p. 372.
† "Elements of Physiology," translated by Dr. Baly; pp. 680, 686.

produced, which is referred by the mind to the parts to which its branches are ultimately distributed; and if only part of the trunk be irritated, the sensation will be referred to those parts only, which are supplied by the fibrils it contains. This is evidently caused by the production of a change in the sensorium, corresponding with that which would have been transmitted from the peripheral origins of the nerves, had the impression been made upon them. Such a change only requires the integrity of the afferent trunk, between the point irritated and the sensorium, and is not at all dependent upon the state of the peripheral part to which the sensations are referred; for this may have been paralysed by the division or other lesion of the nerve, or may have been altogether separated as in amputation, or the relative position of its parts may have been changed as in autoplastic operations. So, when different parts of the thickness of the same trunk are separately and successively irritated, the sensations are successively referred to the several parts supplied by these divisions. This may be easily shown by compressing the ulnar nerve in different directions, where it passes at the inner side of the elbow-joint.—Still the mind undoubtedly does possess a certain power of discriminating the part of the nerve-trunk on which the impression is made; for whilst this impression is such as to produce sensations that are referred to its peripheral extremities, pain is at the same time felt in the spot itself; and it would seem as if slight impressions are *only* felt in the latter situation, at least in the normal condition of the trunk or fibre. Thus, as it has been well remarked by Volkmann, "if a needle's point be drawn in a straight line across the back, or the thigh, or any part in which the nerves are widely placed, the mind perceives the line of irritation as a straight one; whereas, if it referred all impressions to the ends of irritated fibres, this mode of irritation should be felt in sensations variously scattered about the line, at the points where the nerve-fibres crossed by the needle terminate." *

II. The sensation produced by irritation of a branch of the nerve, is confined to the parts to which that branch is distributed, and does not affect the branches which come off from the nerve higher up. The rationale of this law is at once intelligible: but it should be mentioned that there are certain conditions, in which the irritation of a single nerve will give rise to sensations over a great extent of the body. This 'radiation of sensations' seems rather due, however, to a particular state of the central organs, than to any direct communication among the sensory fibres.

III. The *motor* influence is propagated only in a centrifugal direction, never in a retrograde course. It may originate in a spontaneous change in the central organs, or it may be excited by an impression conveyed to them through afferent nerves, but in both cases its law is the same.

IV. When the whole trunk of a motor nerve is irritated, all the muscles which it supplies are caused to contract. This contraction evidently results from the similarity between the effect of an artificial stimulus applied to the trunk in its course, and that of the change in the central

* "Kirkes and Paget's Handbook of Physiology," p. 375.—It does not seem improbable, however, that in the case of the compression or other irritation of a large nerve-trunk, the *local* pain may be produced through the instrumentality of *nervi nervorum*, the existence of which is scarcely less probable than that of *vasa vasorum*.

organs by which the motor influence is ordinarily propagated. But when only a part of the trunk or a branch is irritated, the contraction is usually confined to the muscles which receive their nervous fibres from it; in this instance, as in the other, there is no lateral communication between the fibrils. An exception exists, however, in regard to galvanic irritation, which may be transmitted laterally when its ordinary course is checked; as has been shown by the following ingenious experiment of M. du Bois-Reymond. If any motor nerve be selected which divaricates into two branches (as, for example, the sciatic nerve of a frog, which divides above the bend of the knee into the tibial and peroneal branches), and a galvanic stimulus be applied to either of these branches, this having been first divided above its insertion into the muscles, the electrotonic state will be developed, not merely in the portion of the trunk continuous with that branch, but also in that which is continuous with the other branch, as will be made apparent by the contraction in the muscles supplied by the latter. That this experiment may be free from the possible fallacy resulting from the excitement of reflex action; the trunk of the sciatic nerve should be divided high up, or the spinal cord be destroyed.

690. Various methods of determining the functions of particular nerves present themselves to the Physiological inquirer.—One source of evidence is drawn from their *peripheral distribution.* For example, if a nervous trunk is found to lose itself entirely in the substance of Muscles, it may be inferred to be chiefly, if not entirely, *motor* or *efferent.* In this manner, Willis long ago determined that the Third, Fourth, Sixth, Portio dura of the Seventh, and Ninth cranial nerves, are almost entirely subservient to muscular movement; and the same had been observed of the fibres proceeding from the small root of the Fifth pair, before Sir C. Bell experimentally determined the double function of that division of the nerve into which alone it enters. Again, where a nerve passes through the muscles, with little or no ramification among them, and proceeds to a Cutaneous or Mucous surface, on which its branches are minutely distributed, there is equal reason to believe that it is of a *sensory,* or rather of an *afferent,* character. In this manner Willis came to the conclusion, that the Fifth pair of cranial nerves differs from those previously mentioned, in being partly sensory. Further, where a nerve is *entirely* distributed upon a surface adapted to receive impressions of a *special* kind, as the Schneiderian membrane, the retina, or the membrane lining the internal ear, it may be inferred that it is not capable of transmitting any other kind of impressions; for experiment has shown, that the *special sensory* nerves do not possess common sensibility. The case is different, however, in regard to the sense of taste, which originates in impressions not far removed from those of ordinary touch; and it is probable that the same nerves minister to both.—Anatomical evidence of this kind, is valuable also, not only in reference to the functions of a principal trunk, but even as to those of its several branches, which, in some instances, differ considerably. Thus, some of the branches of the Pneumogastric are especially motor, and others almost exclusively afferent; and anatomical examination, carefully prosecuted, not only assigns the reasons for these functions, when ascertained, but is in itself nearly sufficient to determine them. For the superior laryngeal branch is distributed almost entirely upon the mucous surface of the larynx, the only muscle it supplies being

the crico-thyroid; whilst the inferior laryngeal or recurrent is almost exclusively distributed to the muscles. From this we might infer, that the former is an afferent, and the latter a motor nerve; and experimental inquiries (as we have seen, § 553) fully confirm this view. In like manner it may be shown, that the Glosso-pharyngeal is chiefly an afferent nerve, since it is distributed to the *surface* of the tongue and pharynx, and scarcely at all to the muscles of those parts; whilst the pharyngeal branches of the Pneumogastric are chiefly, if not entirely, motor (§ 427). Lower down, however, the branches of the Glosso-pharyngeal cease, and the œsophageal branches of the Pneomogastric are distributed both to the mucous surface and to the muscles, from which it may be inferred that they are both afferent and motor; a deduction which experiment confirms (§ 428).—We perceive, therefore, that much knowledge of the function of a nerve may be obtained, from the attentive study of its ultimate distribution; but it is necessary that this should be very carefully ascertained, before it is made to serve as the foundation for physiological inferences. As an example of former errors in this respect, may be mentioned, the description of the Portio dura of the Seventh, at first given by Sir C. Bell; he stated it to be distributed to the skin as well as to the muscles of the face, and evidently regarded it as in part an afferent nerve, subservient to respiratory impressions as well as to motions. In the same manner, from inaccurate observation of the ultimate distribution of the Superior Laryngeal nerve, it was long regarded as that which stimulated to action the constrictors of the glottis.

691. But the knowledge obtained by such anatomical examinations alone is of a very general kind; and requires to be made particular,—to be corrected and modified,—by other sources of information. One of these relates to the *connexion of the trunks with the central organs.* The evidence derived from this source, however, is seldom of a very definite character; and, in fact, Physiologists have rather been accustomed to judge of the functions of particular divisions of the nervous centres by those of the nerves with which they are connected, than to draw aid from the former in the determination of the latter. Still, this kind of examination is not without its use, when there is reason to believe that a particular tract of fibrous structure has a certain function, and when the office of a nerve whose roots terminate in it is doubtful. Here, again, however, very minute and accurate examination is necessary, before any sound physiological inferences can be drawn from facts of this description; and many instances might be adduced to show, that the real connexions of nerves and nervous centres are often very different from their apparent ones.

692. Most important information as to the functions of particular nerves may be drawn from *experimental inquiries;* but these also are liable to give fallacious results, unless they are prosecuted with a full knowledge of all the precautions necessary to insure success. Some of these will be here explained.—In the first place, the endowments of the *trunk* and of the *roots* of a nerve may differ; owing to the admixture, in the former, of fibres derived by inosculation from another nerve (§ 688). Hence, in order to attain satisfactory results, a comparative set of experiments should always be made upon each.—A nerve-trunk may be too hastily considered as *motor*, on account of the excitation of muscular

movements by irritation of its trunk, whilst still in connection with its centre; for such movements may be called forth, not only by the direct influence of the nerve upon the muscles, but also by reflex stimulation, acting through the ganglionic centre upon some other nerve. The real nature of such movements can only be determined by dividing the trunk, and irritating each of the cut extremities. If, upon irritating the end *separated* from the centre, muscular contractions are produced, it may be safely inferred that the nerve is, in part at least, of an *efferent* character. Should no such result follow, this would be improbable. If, on the other hand, muscular movement should be produced by irritating the extremity *in connexion with* the centre, it will then be evident, that it is occasioned by an impression conveyed *towards* the centre by *this* trunk, and propagated to the muscles by some other; in other words, to use the language of Dr. M. Hall, this nerve is an 'excitor' of motion, not a direct motor nerve. The Glosso-pharyngeal has been satisfactorily determined, by experiments of this kind, performed by Dr. J. Reid (§ 427), to be chiefly, if not entirely, an afferent nerve.—It has been from the want of a proper mode of experimenting, that the functions of the *posterior* roots of the Spinal nerves have been regarded as in any degree motor. If they be irritated, without division of either root, motions are often excited; but if they be divided, and their separated trunks be then irritated, no motions ensue; nor are any movements produced by irritation of the roots in connexion with the spinal cord, if the *anterior* roots have been divided. Hence it appears that these fibres do not possess any direct motor powers, but that they convey impressions to the centre, which are reflected to the muscles through the anterior roots.—The same difficulties do not attend the determination of the *sensory* endowments of nerves. If, when the trunk of a nerve is pricked or pinched, the animal exhibit signs of pain, it may be concluded that the nerve is capable of receiving and transmitting sensory impressions from its peripheral extremity. But not unfrequently this capability is derived by inosculation with another nerve; as is the case with the Facial, which is sensory after it has passed through the parotid gland, having received there a twig from the Fifth pair. A similar inosculation explains the apparent sensibility of the *anterior* roots of the Spinal nerves. If these be irritated, the animal usually gives signs of uneasiness; but if they be divided, and the cut ends nearest the centre be irritated, none such are exhibited; whilst they are still shown when the farther ends are irritated, but not if the posterior roots are divided. This seems to indicate that, from the point of junction of the two roots, sensory fibres derived from the posterior root pass backwards (or towards the centre) in the anterior; and thus its apparent sensory endowments are entirely dependent upon its connexion with the posterior column of the spinal cord, through the posterior roots.

693. The fallacies to which all experiments upon the nerves are subject, arising from the partial loss of their power of receiving and conveying impressions, and of exciting the muscles to action, after death, are too obvious to require more particular mention here; yet they are frequently overlooked. Of a similar description are those arising from severe disturbance of the system, in consequence of operations; which also have not been enough regarded by experimenters.—As a general rule, *negative* results are of less value than *positive;* but very careful discrimination is

often required to determine what *are* negative, and what positive results. Each particular case has *its* own sources of fallacy, which require to be logically scrutinized; and the only satisfactory proof is derived from the concurrence of every kind of evidence, which the nature of the inquiry admits of. Thus in the determination of the functions of a particular nerve-trunk, it should be shown that a certain effect is constantly produced by its excitation (under the conditions laid-down in the preceding paragraph), and that a corresponding interruption in the action to which it is hence inferred to be subservient, takes place when its continuity has been interrupted: by this double proof, the Glosso-pharyngeal and the Pneumogastric are shown to be the principal, but not the sole, excitors of the movements of Deglutition and Inspiration respectively. But the evidence afforded solely by the interruption of a particular function, after the division of a certain nerve or the destruction or removal of a nervous centre, is by no means so satisfactory; for this may be occasioned rather by the general effects of the operation, than by the simple lesion of the nervous apparatus. In order to get rid, so far as possible, of this source of fallacy (which particularly affects experiments upon the Encephalic centres, and upon the influence of the nerves upon the viscera), it is desirable to perform comparative experiments, in which the general injury shall be as nearly as possible the same, and the only difference shall lie in the lesion of the nervous system; and to subtract from the general result all that can be thus shown to be attributable to the general disturbance produced by the operation. But even then, it may happen that the function is only suspended for a time, by the shock which has been induced by the injury to the nerve; and if it should be subsequently renewed, without any reunion of the trunk, we have the most convincing proof that, whatever degree of participation the nerve may have in it, the action is not essentially dependent upon the integrity of that portion of the nervous apparatus. Such we have seen to be the case in regard to the relation of the Pneumogastric nerves to the secretion of gastric fluid in the walls of the stomach (§§ 445–447).

694. All our positive knowledge of the functions of the Nervous System in general, save that which results from our own consciousness of what passes within ourselves, and that which we obtain from watching the manifestations of disease in Man, is derived from observation of the phenomena exhibited by animals made the subjects of experiments; and in the interpretation of these, great caution must be exercised.—In the first place it must be constantly borne in mind that, except through the *movements* consequent upon them, we have no means of ascertaining, whether or not particular changes in the Nervous System, whose character we are endeavouring to determine, are attended with Sensation; since we have no power of judging whether or not this has been excited, save by the cries and struggles of the animal made the subject of experiment. Now although such cries and struggles are ordinarily considered as indications of pain, yet it is not right so to regard them in every instance; and the only unequivocal evidence is derived from observation of the corresponding phenomena in the Human subject; since we can there ascertain, by the direct testimony of the individual affected, what impressions produce sensation, and what excite movements independently of sensation (§ 674). Further, we are not justified in assuming that Consciousness is excited by

an irritation, still less that Intelligence and Will are called into exercise by it, merely because movements, evidently tending to get rid of its source, are performed in respondence to it. We know that the contractions of the heart and alimentary tube are ordinarily excited by a stimulus, without any sensation being involved; and these movements, like all that are concerned in the maintenance of the Organic functions, have an obvious design, when considered either in their immediate effects, or in their more remote consequences. The character of *adaptiveness*, then, in Muscular movements excited by external stimuli, is no proof that they are performed in obedience to sensation; much less, that they have a voluntary character. In no case is this adaptiveness more remarkable, than in some of those actions, which are not only performed without any effort of the will, but which the will cannot imitate. This is the case, for example, with the act of Deglutition (§§ 427, 428), the muscles concerned in which cannot be thrown into contraction by a voluntary impulse, being stimulated only by impressions conveyed from the mucous surface of the fauces to the Medulla Oblongata, and thence reflected along the motor nerves. No one can swallow, without producing an impression of some kind upon this surface, to which the muscular movements will immediately respond. Now it is impossible to conceive any movements more perfectly adapted to a given purpose, than those of the parts in question; and yet they are independent, not only of volition but of sensation, being still performed in cases, in which consciousness is completely suspended, or entirely absent. The act of Sucking in the infant, again, is one in which a number of muscles are called into combined contraction, in a manner which shows a most complete adaptation to a given purpose; and yet it is impossible to suppose this adaptation to be *purposive* on the part of the infant itself; more especially as it is shown, both by the occurrence of monstrosities, and by experiments made with this object (§ 423), that no part of the Cranio-spinal axis above the Medulla Oblongata is necessary to it. And in the acts of Coughing and Sneezing (§ 555), we have examples of the most *adaptive* movements, executed by a marvellous combination of separate muscular actions, with the obvious purpose of removing a source of irritation from the air-passages; and yet we know by personal experience, that this combination is *not* made with any design of our own.

695. In addition to the Cerebro-Spinal system of ganglionic centres and nerve-trunks, all but the lowest Vertebrated animals possess a system of ganglionic centres scattered in different parts of the body, but mutually connected with each other, as well as with the Cerebro-spinal system; this is commonly termed the *Sympathetic* system; but not unfrequently, from the position of its principal centres, and their evident functional relation to the apparatus of Organic life, the *Visceral* system. To this system, which seldom presents itself in a distinctly recognizable form in Invertebrated animals, we are probably to refer not only the Semilunar and Cardiac ganglia (which seem to be its principal centres), with the chain of cranial, cervical, thoracic, lumbar, and sacral ganglia, which are in nearer connection with the cerebro-spinal system, but also numerous minute ganglia, which are to be found on its branches in various parts, and, in addition, the ganglia upon the posterior roots of the spinal nerves; and if such be the case, those fibres contained in the cerebro-spinal nerves,

ıich have these as their ganglionic centres, must also be accounted as longing to the Sympathetic system. On the other hand, there unquesmably exist numerous fibres in the Visceral system, which proceed into from the Cerebro-spinal system; these, however, are not uniformly stributed, for some of the Visceral nerves contain few or none of them, ıilst in others they are numerous. The branches by which the Sympaıetic system communicates with the Cerebro-spinal, and which were rmerly considered as the *roots* of the Sympathetic system, contain fibres ' both kinds;—*i.e.*, Cerebro-spinal fibres passing into the Sympathetic, ıd Sympathetic fibres passing into the Cerebro-spinal. The latter are ıiefly, if not entirely, transmitted into the *anterior* branches of the Spinal erves; the *posterior* branches being apparently supplied with sympaıetic fibres from the ganglia on their own posterior roots. Some of ıese last fibres also pass from the Cerebro-spinal into the Sympathetic ystem. By these communications, the two systems of fibres are so lended with each other, that it is impossible to isolate them.—The ranches proceeding from the Semilunar ganglia are distributed upon the bdominal viscera; and those of the Cardiac ganglia upon the heart and ıe vessels proceeding from it. The latter seem to accompany the arterial runks through their whole course, ramifying minutely upon their surıce; and it can scarcely be doubted that they exercise an important ıfluence over their functions. What the nature of that influence may be, ıowever, will be a subject for future inquiry. It is so evidently connected vith the operations of nutrition, secretion, &c., that the designation of " nervous system of organic life," as applied to this system, does not seem objectionable, provided that we do not understand it as denoting the *lependence* of these functions upon it.—Even in Vertebrata, however, we do not always find the distribution of the visceral trunks distinct from that of the cerebro-spinal. In the Cyclostome Fishes, the par vagum supplies the intestinal canal along its whole length, as well as the heart; and no appearance of a distinct sympathetic can be discovered. In Serpents, again, the lower part of the alimentary canal is supplied from the spinal cord, and the upper part by the par vagum; and though the lateral cords of the sympathetic may be traced, they are almost destitute of ganglia. Even in the highest Vertebrata, some of the glands, of which the secretion is most directly influenced by the condition of the mind, are supplied with most of their nerves from the cerebro-spinal system; thus, the lachrymal and sublingual glands receive large branches from the fifth pair, and the mammary glands from the intercostal nerves.

### 2. *Of the Spinal Cord and Medulla Oblongata;—their Structure and Actions.*

696. In our more detailed consideration of the functions of the several divisions of the Nervous System, it is desirable, for several reasons, to commence with the *Cranio-Spinal Axis;* which, as already pointed out (§ 678), may be considered as constituting the fundamental portion of this apparatus. The entire Axis is divided into its Cranial and its Spinal portions, the passage of the Cord through the foramen magnum of the occipital bone being considered to mark the boundary between them; and although the separation of the Medulla Spinalis from the Medulla Oblon-

gata, which is thus established, is in itself purely artificial, yet it will be found to correspond completely with the natural division founded on their respective physiological attributes.—The *Spinal Cord*,* then, which extends from the margin of the foramen magnum to the first or second lumbar vertebra, and which is prolonged as the *filum terminale*† to the extremity of the sacral canal, is almost completely divided by the *anterior* and *posterior median fissures* (Fig. 129), into two lateral and symmetrical halves. The 'anterior median fissure' (*a*) is more distinct than the posterior, being wider at the surface; but it only penetrates to about one-third of the thickness of the Cord, its depth increasing, however, towards its lower part. The sides of the 'posterior median fissure' (*p*), on the other hand, are in closer approximation; but the division commonly extends to about half the thickness of the cord, being deeper towards its upper than towards its lower end. The two halves, therefore, are only united by a commissural band which occupies the central part of the cord, and this is traversed by the 'Spinal canal' (*f*), which is continued downwards from the fourth ventricle.‡ At a little distance from either side of the posterior median fissure, and corresponding with the line of attachment of the posterior roots of the nerves, is the *posterior lateral furrow;* a shallow longitudinal depression, which marks-out the 'posterior columns' of the Cord as distinct from the 'antero-lateral columns.' A corresponding furrow has been sometimes described as traversing the Cord in the line of the anterior roots of the nerves on either side; but this can scarcely be said to have a real existence; and the separation of the 'antero-lateral columns' into the 'anterior' and the 'lateral' columns, is only marked externally by the attachment of the nerve-roots, but is made more obvious internally by the peculiar distribution of the grey matter. These columns are entirely composed of nerve-fibres, whose general direction is longitudinal; and of these fibres it is quite certain that some are directly continuous with those which constitute the roots of the spinal nerves. It has been generally considered by Anatomists, that the anterior roots are chiefly connected with the anterior columns, but that some of their fibres are also continuous with the lateral columns; and that the posterior roots are in like manner connected chiefly with the posterior but also with the lateral columns. Some have maintained, on the other hand, that both sets of nerve-roots are connected with the lateral columns exclusively. According to the most recent researches, however, it appears that the anterior roots are directly connected with the anterior columns only, and the posterior roots with the posterior, columns alone; but of those fibres from both these roots which pass at first into the grey matter, a certain proportion emerge from this and enter the lateral columns.—To what extent any of these fibres proceed along the columns of the

* The sketch given in the text of the anatomy of the Spinal Cord is chiefly derived from the statements of Prof. Kölliker in his "Mikroskopische Anatomie" (Band II, §§ 115, 116), and of Mr. J. L. Clarke in the "Philosophical Transactions," 1851; between which there is a general accordance.

† The structure of the 'filum terminale' is in every respect essentially the same as that of the proper Spinal Cord, save that no nerve-roots are connected with it.

‡ The spinal canal is much more obvious in Fishes; and the commissural connection between the two halves of their spinal cord is far less distinct than in higher Vertebrata. The canal can only be distinguished in Man, being no more than 1-100th of an inch in diameter, by submitting thin transverse sections of the Cord to microscopic examination.

›inal Cord, no precise anatomical evidence has yet been obtained; and though there are appearances which may be regarded as sanctioning ıe idea, that a direct and continuous communication is established by ·eir means between the roots of the nerves and the encephalic centres, ›t there are difficulties in such a view of the case, which must be taken ıto account in our physiological consideration of it (§ 700).

697. The 'grey matter' of the Spinal Cord is readily brought into view y making transverse sections in different parts; and although its distri- ution is by no means uniform, yet on the whole it may be described as ›nstituting (when thus exposed) two somewhat crescent-shaped masses Fig. 129), whose convexities are turned towards each other, and are con- ected by the grey commissure, whilst their cornua are directed towards ıe surface of the cord, the posterior peak on either side reaching the osterior lateral furrow, whilst the anterior, though the larger cornu, does ot approach quite so near to the surface. This grey matter, however, is y no means uniform in its texture throughout. A considerable part of he posterior cornua is destitute of vesicular or ganglionic corpuscles, and s known under the name of *substantia gelatinosa* (*g*); it has been lately hown by Mr. J. L. Clarke, however, that a tract of vesicular matter does xist on either side (*e*), in intimate connection with the posterior roots of he nerves, and that this may be traced continuously from the lower extre- ıity of the spinal cord to the medulla oblongata where it terminates, and hat it increases in size in the lumbar and cervical enlargements. The grey ıatter of the anterior cornua, which has been distinguished as the *sub- tantia spongiosa*, contains a large amount of vesicular structure (*d*, *d*), he number of vesicles being constantly in direct proportion to the size of he nerve-roots in connection with it. The vesicles are of the stellate haracter, each having several prolongations which seem to unite with hose of other vesicles; and hitherto it has not been found possible to race any direct passage of these prolongations into nerve-fibres. The ommissure is formed entirely, according to Mr. J. L. Clarke, by the ibrous portion of the grey matter, neither the anterior nor the posterior olumns having any direct connection by transverse fibres; and the entral part of it is stated by him to consist of a layer of fine fibrous issue surrounding the wall of the spinal canal, which is lined with a layer of columnar epithelium. The fibres of the grey substance and even those of the substantia gelatinosa, are tubular, but are of extremely minute ize, their average diameter not exceeding 1-10,000th of an inch, and ome of them measuring as little as 1-15,000th or 1-16,000th.—The ourse of the fibres which constitute the roots of the Spinal Nerves, as een in transverse sections of the Cord, is thus described by Mr. J. L. Clarke. The bundles of fibres which form the *posterior* root (Fig. 129, ;, *c*) are much larger, but less numerous than those of the anterior; the fibres themselves are mostly finer and more delicate, their average dia- meter being about 1-7000th of an inch. On entering the posterior columns of the Cord, the fasciculi traverse them obliquely inwards, interlacing and forming with each other an intricate plexus. From this plexus, straight and distinct bundles enter the posterior cornua along their whole breadth, and cross the 'substantia gelatinosa' both obliquely and at right angles; some being immediately continuous with fibres of the transverse commissure, some passing to the vesicular tract, while

others break up and form a finer network which extends towards the anterior cornua. Some of these fibres, after traversing the grey substance, pass out again into the posterior and lateral white columns; and many of

Fig. 129.

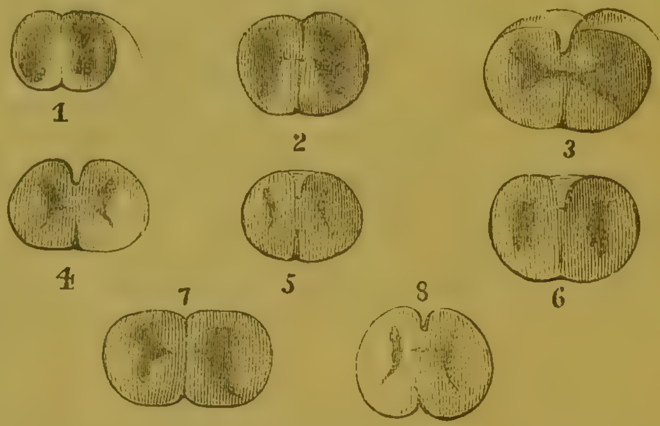

Transverse section of *Human Spinal Cord*, through the middle of the lumbar enlargement, showing on the right side the course of the nerve-roots, and on the left the position of the principal tracts of vesicular matter:—A, A, anterior columns; P, P, posterior columns; L, L, portion of lateral columns; *a*, anterior median fissure; *p*, posterior median fissure; *b*, *b*, *b*, *b*, anterior roots of spinal nerves; *c*, *c*, posterior roots; *d*, *d*, tracts of vesicular matter in anterior column; *e*, tracts of vesicular matter in posterior column; *f*, spinal canal; *g*, substantia gelatinosa.

those of the 'substantia gelatinosa' seem to become longitudinal. The fasciculi of fibres which constitute the *anterior* roots, on the other hand, traverse the anterior columns of the Cord somewhat obliquely, and in straight and distinct bundles, which do not interlace with each other, but proceed directly to the anterior grey cornu. On reaching this, they break up into smaller bundles and separate fibres, which diverge in various directions; of those proceeding towards the external border of the cornu, some pass out again into the antero-lateral column, whilst others, after winding round groups of caudate vesicles, curve inwards and join the fibres of the transverse commissure; of those proceeding along the inner border of the cornu, a few pass into the white column at the side of the median fissure, while others, entering the anterior portion of the transverse commissure, cross to the opposite side; and the remainder, plunging into the central portion of the cornu, and winding among its vesicles, seem to lose themselves in its substance, some of them probably changing their direction and becoming longitudinal. According to Stilling, an

absolute continuity is thus established between certain of the anterior and posterior root-fibres of the same side; and also between the anterior fibres of one side and the posterior of the other, through the transverse commissure. The evidence which he has adduced in favour of this doctrine, however, is by no means satisfactory; and for the present it must be regarded as hypothetical. That an actual decussation of the fibres of the Cord is effected by means of the transverse commissure, although denied by Hannover, seems to have been fully proved by Mr. J. L. Clarke; this decussation, however, is limited, as already stated, to the fibres of the grey matter.*

698. The Spinal Cord is by no means of uniform dimensions throughout its length, but presents an enlargement at the origins of the large nerves forming the brachial and crural plexuses. This enlargement is produced by an increase in the quantity both of the grey and of the white substances; and it is obviously comparable to the enlargement of the ganglia of the ventral cord of Articulata, which presents itself in connection with the nerves of the special locomotive organs, as we well see in tracing the alterations which this cord undergoes between the 'larva' and 'imago' states of the Insect.† Its relation to the functions of these nerves is further indicated by the constancy with which it presents itself, through the entire Vertebrated series, in those parts of the Cord from which the largest supply is transmitted to the locomotive organs. In most Fishes, for example, the body being propelled through the water rather by the lateral action of the flattened trunk and tail (with that of the median fins), than by the movements of the extremities which serve principally to guide it, the size of the Cord usually varies but little through its whole length; and this is especially the case with the Eel and other vermiform apodal fishes. But in the Flying-fish, and others whose pectoral fins are unusually powerful, a distinct ganglionic enlargement of the cord presents itself where their nerves are given off. In Serpents, again, the spinal cord is nearly uniform throughout its entire length;

Fig. 130.




Transverse sections of *Human Spinal Cord* at different points, showing the proportional quantity and arrangement of grey and white matter at each:—1, opposite 11th dorsal vertebra; 2, opposite 10th dorsal; 3, opposite 8th dorsal; 4, opposite 5th dorsal; 5, opposite 7th cervical; 6, opposite 4th cervical; 7, opposite 3rd cervical; 8, section of medulla oblongata through centre of corpus olivare.

* Mr. J. L. Clarke has succeeded in preparing transverse sections of the Cord of sufficient thinness to enable them to be seen under high powers with transmitted light; whereas the statements of Stilling, and of other observers who have used his method, have been founded upon observations made upon comparatively opaque sections seen under low powers, and often with reflected light, whereby the nature of the several structures was often left in obscurity.

† See "Princ. of Phys., Gen. and Comp.," § 776.

whilst in Amphibia it is so during the Tadpole condition, but presents enlargements corresponding to the anterior and posterior extremities, when these are developed; at the same time becoming much shortened, as the tail is less important to locomotion, or is altogether atrophied. In Birds, the ganglionic enlargements are generally very perceptible, and bear a close relation in size with the development of the locomotive organs with which they are connected: thus in birds of active flight, and short powerless legs, the anterior enlargement is the principal; but in those which are more adapted to run on land than to wing their way through the air, such as the whole tribe of Struthious birds, the size of the posterior enlargement is very remarkable; and this exactly corresponds with what has been observed in the Articulated classes, and especially in watching the metamorphosis of Insects. In Birds and Mammalia, however, the whole amount of the grey matter in the spinal cord does not bear so large a proportion to the bulk of the nerves proceeding from it, as in the lower Vertebrata; and the reason of this seems obvious. The actions of the locomotive organs are less and less of a reflex character, and are more directly excited by the will, and consequently by the brain, than in the inferior tribes; and just in proportion, therefore, to the development of the Brain, will *it* become the moving spring of all the actions performed by the animal, and the Spinal Cord be merely its instrument. Still, in all the Mammalia, as in Man, do we find these ganglionic enlargements of the spinal cord; and in Man it is the posterior one (or rather the inferior), which contains the largest quantity of grey matter.

699. No doubt is now entertained amongst Physiologists, that the Spinal Cord is to be regarded under a double aspect;—on the one hand, as an independent centre of nervous power, on which excitor impressions operate to produce reflex movements;—and, on the other, as the channel of communication between the roots of the spinal nerves and the encephalic centres, whereby sensory impressions are transmitted upwards to the sensorium, and motor influences originating in the brain are transmitted downwards to the efferent nerves. But with regard to what may be termed the mechanism by which this is effected, there is at present a considerable diversity of opinion; which arises out of the difficulty of determining, on the one hand, whether any of the root-fibres actually terminate in the grey matter of the Cord, and, on the other, whether the longitudinal fibres of the white columns are actually continuous from the Medulla Oblongata to the roots of the Spinal nerves. Three distinct notions of this mechanism at present have their several advocates amongst Anatomists of distinction.

I. According to the first view, which may be regarded as a modification of the doctrine which was current before the independent power of the Spinal Cord had been distinctly recognized, *all* the root-fibres of the Spinal nerves are brought by means of its longitudinal columns into direct continuity with the *Encephalic* centres; so that sensory impressions are transmitted upwards to the sensorium, and motor impulses are transmitted downwards from the seats of volition, emotion, &c., without any interruption. But these fibres *pass through* the grey substance of the Spinal Cord, in their transit from the white columns to the nerve-roots, and are thus subjected to the influence of its vesicular matter, which is

capable of exerting an independent operation through them, especially when their continuity with the Brain is interrupted.

II. According to the second view, the *Spinal Cord* is the real ganglionic centre of *all* the root-fibres of the nerves issuing from it; each pair of nerves being thus directly connected only with its own segment of the cord, or with other segments a little above or below this; and the function of the white or longitudinal columns being to establish a commissural connection between the several segments of the Cord, and to bring them into connection also with the Encephalic centres. On this hypothesis, no sensory impressions pass directly from the Spinal nerves to the Sensorium, and no motor impulse is directly transmitted from any part of the Encephalon to these nerves, the vesicular matter of the Spinal Cord being in each case the immediate recipient of the change, and serving (so to speak) as a fresh starting-point for the nerve-force; whilst, if the connection of any segment with the Encephalon be interrupted, that segment reacts upon impressions transmitted to it, in virtue of the direct connection of the nerve-roots with its own ganglionic centre.

III. The third view is a combination of both the preceding doctrines; for it is considered by those who advocate it, that certain of the root-fibres, passing continuously along the longitudinal columns of the Cord, establish a direct connection, for sensory and motor purposes, between the Spinal nerves and the Encephalic centres; whilst certain other fibres have their central termination in the grey matter of the Cord itself. It is considered on this hypothesis, that the fibres which minister to sensory impressions, do so in virtue of their direct and continuous passage from the peripheral surface to the sensorium; whilst the fibres which transmit downwards from the Encephalic centres the motor impulses originating in them, pass continuously to the muscles which they call into play. On the other hand, each segment of the Cord is considered to minister to its own reflex action; the different segments, however, possessing such a commissural connection with each other, that an impression made upon one of them may be transmitted to many others, and may excite reflex movements through them.—Among those who hold this view, however, there is a very considerable difference of opinion with regard to the real centre of the Encephalic fibres; some maintaining that they *pass through* the Corpora Striata, Thalami Optici, and other Sensory Ganglia, to the peripheral vesicular matter of the Cerebrum; whilst others hold that the real *termination* of all of them is in the Sensory Ganglia, and that the Cerebrum has therefore no connection with them, otherwise than through the intermediation of those bodies. Although this question may be considered as rather related to the structure and functions of the Encephalic centres, than to that of the Spinal Cord, yet it has such a bearing upon the function assigned to the longitudinal fibres of the Cord, that it must be taken into account in the present discussion.

700. The principal argument for the doctrine (which seems to have originated with the anatomical researches of Stilling and Wallach,* and to have been first put forth on a physiological basis by Messrs. Todd and Bowman †) that the Spinal Cord is the real centre of all the nerve-fibres

* "Untersuchungen über die Textur des Rückenmarks," Leipzig, 1842.
† "Physiological Anatomy and Physiology of Man," Part ii., 1845.

connected with it, arises from the asserted difficulty of supposing that its longitudinal columns *can* transmit any considerable number of nerve-fibres from the Encephalon to the Spinal nerve-roots. Thus it is urged by Dr. Todd, that it is highly improbable that the only channel by which the Will can influence the spinal nerves should be (as generally admitted) that afforded by the Anterior Pyramids; since the whole bulk of these pyramids on *both* sides, taken together, scarcely equals that of *one* of the anterior portions of the antero-lateral columns. Moreover, if there were a gradual giving-off of Encephalic fibres from the longitudinal columns into the roots of the nerves, the size of these columns ought progressively to diminish from above downwards; whereas it is asserted by Volkmann, who has strenuously upheld this doctrine,* that the size of the white columns presents no such diminution, but that it is everywhere proportional to the quantity of grey matter in the Cord. Thus in Serpents, the Spinal cord (as already noticed) is remarkable for its uniformity of dimension through its entire length, the absence of limbs preventing the necessity for an increase in the quantity of grey matter in any part, and the fibrous columns presenting a similar uniformity throughout; whereas, if the latter be really Encephalic, they should gradually dwindle-away from the head to the tail. Moreover it has been estimated by Volkmann that the area of the whole Spinal Cord of a Boa, at its anterior part, is not more than *one-eleventh* part of the united area of the 221 pairs of nerves which are given off from it. Further, it is urged by Volkmann, that the white columns are absolutely smaller in the cervical region, than they are in the lower part of the cord, so that they would not suffice to convey even the lumbar columns upwards to the Encephalon, much less to transmit the fibres of all the intervening nerves in addition. Thus having weighed four pieces of a Horse's spinal cord, all of the same length, and taken respectively from below the second, eighth, nineteenth, and thirtieth pairs of nerves, he found that their weights were respectively 219, 293, 163, and 281 grains; and that the transverse sections of the grey matter gave respectively the area of 13, 28, 11, and 25 square lines, whilst those of the white matter measured 109, 142, 89, and 121 square lines. Hence the greatest amount of fibrous as well as of grey substance is found in those enlargements of the cord which are the ganglionic centres of the nerves of the extremities; these being the parts from which the second and fourth segments were taken in the preceding experiment. On the other hand, in the middle dorsal region, the amount of fibrous structure appears reduced to its minimum; and in the upper cervical region it is considerably less than in the segments below.—These and similar statements, however, have been recently met by Prof. Kölliker,† who inclines to the first of the doctrines stated in the preceding paragraph; his own researches having led him to a conclusion opposed to that of Volkmann, although he was at one time disposed to coincide with it. He has assured himself that in Man the thickness of the white columns augments from below upwards, and that the increase in the diameter of the Cord at the ganglionic enlargements is due to the augmentation of the

* See his valuable article 'Nervenphysiologie,' in Wagner's "Handwörterbuch der Physiologie."

† "Mikroskopische Anatomie," Band ii. § 116.

grey matter only. Moreover, the diameter of the nerve-tubes in the Cord, especially at its upper part, is so much smaller than the diameter of the nerve-tubes of the Nerve-roots, that a large allowance must be made for this difference in estimating the relative number of nerve-tubes in the fibrous columns of the Cord and in the spinal Nerves; and he asserts from actual measurement, that it is by no means impossible for the fibrous strands of the former to contain all the nerve-tubes which issue from them in the latter. He has found himself unable, moreover, to detect *any* termination of nerve-fibres in the vesicular substance of the spinal cord; and hence he thinks it probable that they all pass upwards to the brain.

701. The researches of Prof. Kölliker have thus shown it to be quite possible that many of the nerve-fibres (to say the least) do pass continuously between the Encephalon and the nerve-roots; whilst there is an antecedent probability, derived from the relation of these fibres to the vesicular substance of the Cord, and from the attributes of each segment of the cord as an independent ganglionic centre, that some of them terminate there. This probability becomes very strong, when the Spinal Cord is compared with the ventral column of the Articulata; for it may be stated with certainty, that some of the root-fibres of the nerves proceeding from the latter have their ganglionic centres in the vesicular matter of the ganglia; whilst it is equally certain that some of the fibres pass along the purely fibrous tract of the cord, directly to the cephalic ganglia, which they thus connect with the roots of all the nerves.* But this fibrous tract terminates in the Cephalic ganglia, which are homologous, as already remarked (§ 674), not with the whole Encephalon of Vertebrata, but with their 'sensory ganglia' alone; and thus analogy would lead us to suppose, that the fibrous strands of the Spinal Cord do *not* pass on continuously to the Cerebrum, but really extend no further upwards than the Corpora Striata, Thalami Optici, and the other ganglionic centres in connection with them, which lie along the floor of the cranial cavity. This view will be hereafter shown (Sect. 3) to be in harmony with anatomical and physiological facts, which indicate that the Cerebrum only receives its impulses to action through the medium of the Sensory Ganglia, and that it reacts upon the muscular apparatus only through the same channel. That some of the afferent fibres of the spinal nerves should pass continuously upwards to the ganglia of tactile sense in Man and other Vertebrata, as well as in Articulated animals, would seem a legitimate deduction from the fact that such continuity obviously exists between the olfactive, visual, and auditory nerves, and *their* respective ganglionic centres, no intermediate apparatus of vesicular matter being interposed in their course; and there seems no reason why the motor fibres which are instrumental in those movements that are dependent upon antecedent or co-existent sensations, should not pass continuously from these sensorial centres to the muscles which are called into action. If such be the case, it does not seem at all improbable that there should

* See "Princ. of Phys., Gen. and Comp.," § 768.—The important facts here referred to, have been chiefly substantiated by the researches of Mr. Newport; a very important addition to his statements, however, has been recently made by M. Günther, who has demonstrated the actual continuity between the nerve-fibres and the caudate vesicles, in the ganglia of the ventral cord of the Leech.

be a difference in different tribes of animals, as to the proportion of fibres which have their centres in the Spinal cord and in the Sensorial centres respectively; for in those whose ordinary movements of progression, &c. are independent of sensation, being performed through the reflex action of the spinal cord, it might be expected that the chief connection of the spinal nerves should be with its own ganglionic substance, and that the bulk of the fibrous columns should be composed of commissural fibres resembling those which intervene between the separate portions of the ganglionic tract of the ventral cord of Articulata; whilst in like manner it might be anticipated that in Man, so large a part of whose movements are performed in obedience to a mental stimulus and under the guidance of sensation, the longitudinal strands should be chiefly composed of fibres that directly connect the sensorial centres with the roots of the spinal nerves. Such a difference would appear, from the comparative researches of MM. Volkmann and Kölliker, to exist between the structure of the Spinal cord of the Horse and that of Man.

702. Of the three doctrines previously stated, then, the third appears to be most in conformity with the analogy of the lower animals; whilst it is fairly justified by all that is certainly known of the anatomical structure of the Spinal Cord in Man. When originally advanced by Mr. Grainger,* its novelty chiefly consisted in the idea that *any* of the root-fibres of the spinal nerves have their central termination in the Spinal Cord; and no doubt was at that time entertained by Anatomists or Physiologists, that the Encephalic fibres pass onwards continuously to the peripheral surface of the Cerebrum, and directly minister to voluntary movement as well as to sensation. Consequently, Mr. Grainger's view of the constitution of the Spinal Cord was considered by many Physiologists (among whom the Author is not ashamed to have himself ranked) as affording the needed structural confirmation to Dr. Marshall Hall's hypothesis of a system of nerve-fibres ministering to the reflex action of the Cord, physiologically distinct from those which are subservient to sensation and voluntary movement. But when that distinction is made between the several Encephalic centres which there now appears ground for relying-on, those fibres which connect them with the Spinal nerves are no longer to be accounted Cerebral, nor to be regarded as ministering to volition; but, on the other hand, are to be considered as merely Sensorial, and as belonging, no less than the fibres which link-together the several segments of the Spinal Cord itself, to the 'automatic apparatus' (§ 677).—Thus the view here advocated has a close *physiological* resemblance to the doctrine of Messrs. Todd and Bowman, Volkmann, &c.; whilst it is in full conformity with the *anatomical* facts supplied by Prof. Kölliker; for whilst it recognizes the white columns of the Spinal Cord as chiefly composed of fibres which form a continuous connection between the nerve-roots and certain Encephalic centres, it regards these fibres as really *of the same order* with those which are generally admitted to pass from the nerves of one segment of the Spinal Cord to other segments above and below it, the only difference being that they extend themselves to its cranial segments; and it considers the entire 'automatic apparatus' as receiving all the terminations of the nerves,

* "Observations on the Structure and Functions of the Spinal Cord," 1837.

so that all impressions upon the afferent nerves first operate upon it (affecting the consciousness, or not, according as they reach the sensory ganglia, or are arrested in their progress thither), and all motor impulses, whether simply-reflex, or originating in emotional or volitional excitement, are issued from it through the nerve-trunks to the muscles.

703. In considering the functions of the Spinal Cord, we have to regard it under two aspects;—in the first place, as a *conductor* of nervous force between the Nerve-trunks and the Encephalic centres;—and in the second place, as itself *an independent centre* of nervous power. As a mere conductor of nervous force, its functions are the same as those of a nerve-trunk; for if it be divided, all the parts of the body which are solely supplied by nerves coming off below the point of section, are completely paralyzed as far as regards sensibility and voluntary movement; no impressions made upon them having the least power to affect the consciousness, and no exertion of the will being able to determine contraction of their muscles. This state of *paraplegia,* which may be experimentally induced in animals, is frequently exhibited in Man as a result of injury or of disease which seriously implicates the Spinal Cord; and as it has been shown that among the lower animals complete reunion of the Cord may take place after complete division, as indicated by the entire restoration of its functional powers and the complete redintegration of its structure (§ 349), so have we reason to believe that a similar regeneration may take place to a considerable extent in Man, this being marked by the gradual return of sensibility and power of voluntary movement in the lower limbs which had been at first completely paralysed. This regeneration is of course less likely to occur in cases of disease, when the parts around are in an unhealthy state, than when the paralysis is due to injury, which all the restorative powers of the system are engaged in repairing: but it is to be remembered, that as the injuries which are likely to cause such lesions of the Cord are nearly always attended with severe concussion (it being very rare for it to be accidentally wounded by the penetration of a sharp instrument between the vertebræ, in the mode in which experiments are made upon animals), some of their first effects are attributable to the *shock* which it has sustained; so that the partial recovery which takes place at an early period, must not be regarded as the result of regeneration of nervous tissue, which requires a much longer time for its completion.

704. The conducting power of the entire Spinal Cord being thus established, we have next to inquire whether any difference in endowment can be shown to exist in its several columns. By Sir C. Bell, it was supposed that the anterior columns possess the same endowments as the anterior roots of the nerves, and the posterior columns the same as the posterior roots; and this view is supported by the experiments of Longet,* who deduces from them the conclusion, that irritation of the *posterior* columns, as of the posterior nerve-roots, gives rise to excruciating pain, without exciting any other movements than such as are called into action in reflex respondence to the impression, and that irritation of the *anterior* columns excites movements directly (or without reflexion),

* "Anatomie et Physiologie du Système Nerveux," 1842; and "Traité de Physiologie," 1850, tom. ii. pp. 184–8.

and is not a source of pain. Again, he found that when the Spinal Cord was completely divided, and time was allowed for the reflex activity of the cord to subside (this disappearing rapidly in adult warm-blooded animals) the application of an electric current to the posterior columns of the separated part occasioned no movement whatever, whilst its transmission through the anterior columns called forth vigorous movements. Moreover, he states that the effects of the reversal of the electric current, transmitted through the anterior columns, were the same as those of the same reversal when the currents were transmitted through the anterior roots of the spinal nerves; whilst they differed from those produced by the same change in the direction of the currents, transmitted through a nerve of mixed endowments.—The researches of Van Deen* lead on the whole to the same conclusions: but they tend, in his opinion, to show that the conducting power both of the anterior and posterior columns is very imperfect, if their white strands be completely separated from their grey matter. His experiments appear to have conclusively established that the grey matter, as well as the white, possesses conducting powers; as we might indeed anticipate from the circumstance, that it contains a large amount of the fibrous form of nerve-tissue, and that the commissural connection between the two lateral halves of the Cord is established (according to Mr. J. L. Clarke, § 696) by its grey substance alone. That a ready transverse communication exists, is proved not merely by the fact that an impression made upon a nerve of one side will very commonly excite reflex movements on both; but also by the experiment of completely dividing one half of the cord as far as the median line, and dividing the other half to the same extent a short distance below the first section; for this operation does interrupt the transmission of sensory impressions, although it seems doubtful whether motor influences can be thus propagated.†—The experimental results of Stilling,‡ again, are on the whole in harmony with the preceding; but he lays yet greater stress than Van Deen on the importance of the grey matter to even the conductive power of the white.—These deductions, however, are strongly opposed by Longet; who affirms that he could never obtain any evidence either of sensibility or of motor power, on irritating the grey substance alone by the electric current; and that, on the other hand, the entire destruction of the grey matter for a considerable length, by means of a rod introduced into the interior of the Cord, did not seem in any degree to impair the conducting power of its columns.—It must be borne in mind, however, that there are numerous pathological phenomena, which it is very difficult to reconcile with the foregoing conclusions regarding the relative functions of the anterior and posterior columns of

* "Traités et Découvertes sur la Physiologie et la Moëlle Epinière," Leide, 1841.

† A case is cited by Longet from Begin, in which a man was stabbed at the back of the neck, the point of the knife passing obliquely forwards between the sixth and seventh cervical vertebræ, dividing the antero-lateral and anterior columns of the Spinal Cord on the right side. He survived the injury six days; and suffered from complete paralysis of motion of the corresponding lower extremity, with incomplete paralysis of motion of the right arm: the sensibility remaining perfect. This case seems to show that the Will has no power to direct its motor impulses across the cord; since the parts deriving their nerves from the part of the cord below the partial section, were entirely withdrawn from its influence.

‡ "Untersuchungen über die Functionen des Rückenmarks und die Nerven," Leipzig, 1842.

the Spinal Cord; cases having occurred, in which complete destruction of the anterior columns appeared to have taken place, without loss of voluntary motion in the parts below; whilst a similar destruction of the posterior columns has occurred without corresponding lesion of sensibility.* But it must be borne in mind that we are still far from having an accurate knowledge of the degree of structural change in the nervous centres, which is incompatible with the continued performance of their functions; and that there are instances in which the whole thickness of the cord has undergone softening and apparent disintegration, without the destruction of the functional connection between the Encephalon and the parts below the seat of the disease.†

705. It is difficult to reconcile with the experimental results already cited, those of other Physiologists, which appear to show that the anterior and posterior divisions of the Spinal Cord respectively minister to the motions of flexion and extension. This notion, which originated with Bellingeri,‡ was afterwards advocated by Valentin,§ who inferred from his experiments, that if the *posterior* column of the Spinal Cord of the Frog be irritated at the point at which the nerves of either extremity are given off, that extremity is *extended*, and that if the *anterior* column be irritated, the extremity is *flexed;* so that, since he admitted the anterior columns to be chiefly motor, and the posterior to be for the most part sensory, it would appear that the motor fibres of the extensors pass from the anterior into the posterior column, whilst those of the flexors are continued onwards in the anterior column. Confirmation of this inference was obtained by Valentin from experiments on Mammalia; and it is borne-out, according to him, by pathological phenomena observed in Man. According to this eminent physiologist, also, relaxation of the sphincters is analogous to the extended state of the extremities; and he has noticed a manifest relaxation of the sphincter ani in the frog, when the superior part of the spinal cord was irritated, so as to produce extension of the limbs. The experiments of Budge|| and Engelhart,¶ however, led them to an opposite conclusion; for it appeared to them that, in Mammalia, the nerve-fibres which act upon the *extensor* muscles are contained in the *anterior* columns, and those of the *flexor* muscles in the *posterior* columns; whilst, as regards the Frog, the nerve-fibres connected with the extensor muscles appeared to be situated posteriorly to those of the flexors. The experiments of Harless,** again, have led him to regard

* See especially the case recorded by Mr. Stanley in "Med.-Chir. Transact.," vol. xxiii. and by Dr. Webster, Op. cit., vol. xxvi.

† See, for example, the case of 'Softening of the Spinal Marrow,' recorded by Dr. Nairne in the "Med.-Chir. Trans.," vol. xxxiv.; in which a portion of the Cord at least an inch long, situated opposite the third and fourth dorsal vertebræ, was "so soft that the slightest pressure of the finger broke it up," being nearly in a fluid state through its whole thickness; yet the patient felt *pain* in his lower limbs, showing that the power of *upward* transmission remained; and, although he had lost all voluntary control over the muscles of the lower part of the body, yet they were affected with incessant *choreic* movement (which, as will be shown hereafter, Sect. 7, appears to originate in the Sensory Ganglia), and these movements were affected in such a marked manner by *emotions*, as plainly to indicate a *downward* transmission of motor power.

‡ "De Medullâ Spinali, nervisque ex eâ prodeuntibus," &c., Turin, 1823.

§ "De Functionibus Nervorum Cerebralium et Nervi Sympathici," Bernæ, 1830.

|| "Unter suchungen überdas Nervensystem," 1841.

¶ "Müller's Archiv.," heft 3, 1841.

** "Müller's Archiv.," 1846.

the *upper* part of the spinal cord in the Frog, between the 2nd and 4th vertebræ inclusive, as specially concerned in the *flexion* both of the anterior and posterior extremities; and the *lower* part, from the 5th to the 8th vertebræ inclusive, as in like manner concerned in their *extension.*—All these results can only at present be accepted as indicating that some such special arrangement of the nerve-fibres in the Spinal Cord, having reference to the combination of different muscular actions in groups, may have a real existence; there is far too little accordance, however, among the phenomena described by different observers, to enable even a probable statement to be hazarded in regard to the nature of this arrangement; and it seems quite possible that it may vary in different animals, in accordance with their respective modes of progression. As far as Man is concerned, we have no evidence but that of pathological phenomena; and we certainly may find, in many forms of convulsive action, an indication that there is some common centre or tract of motor impulse for the extensor muscles generally, and another such centre or tract for the flexors.

706. We have now to consider the Spinal Cord as an independent centre of nervous power, and to inquire whether the movements which are excited through its 'reflex' activity really involve sensation. These movements are most characteristically displayed, when the Spinal Cord is cut off from communication with the higher Nervous centres; probably rather because the nerve-force excited by the impression reacts through the Spinal ganglion to which it is conveyed, when it can no longer pass on to the Encephalic centres (§ 683), than because (as some suppose) the impulse to reflex movement is ordinarily neutralized and rendered inoperative by an effort of the will. It is true that those reflex actions of the Spinal Cord which are necessary to the maintenance of Organic life, and which are equally performed whether the Spinal axis be in communication with the higher Encephalic centres or not, are continually modified or temporarily suspended by the Will; but this is only when we consciously bring the Will to bear upon them; and it is no less certain that we are *not* continually making any such exertions, in order to antagonize movements, which (as we learn from Pathological evidence), would be continually excited but for this neutralizing influence, if such a doctrine were correct.—The readiest demonstration of the independent power of the Spinal Cord, is derived from the motions exhibited by the limbs of animals, when irritation is applied to them after section of the Spinal Cord at some point above the entrance of their nerves; the fact that these movements are reflected through the Cord, and are not the product of direct stimulation applied to the part irritated, being shown by their complete cessation when the nerve-trunks are divided, or the substance of the Spinal Cord is broken down. Further, it is to be observed that a slight irritation applied to the peripheral *extremities* of the afferent nerves, is a more powerful excitor of reflex action than a much stronger impression, which occasions acute pain, applied to their *trunks;* thus Mr. Grainger found that he could remove the entire hind-leg of a Salamander with the scissors, without the creature moving, or giving any expression of suffering, if the Spinal Cord had been first divided; yet that by irritation of the foot, especially by heat, in an animal similarly circumstanced, violent convulsive actions in the legs and

ail were excited. This fact is important, not only as showing the com- ıaratively powerful effect of impressions upon the cutaneous surface, but lso as proving how little relation the amount of reflex action has to the ntensity of sensation. That the movements executed by the limbs of he lower animals, when these are no longer connected by the Spinal Cord vith the Encephalon, but remain connected with the Cord itself, do not ake place through the intermediation of sensation, might be supposed to e sufficiently proved by the simple fact, that division of the Cord, in Man, and hence by inference in the lower animals, reduces the parts elow to a state of complete insensibility. But, on the other hand, the very performance, by decapitated animals of inferior tribes, of actions which had not been witnessed in Man under similar circumstances, has been held to indicate, that the spinal cord in them has an endowment which *his* does not possess. The possibility of such an explanation, however unconformable to that analogy throughout organized nature, which, the more it is studied, the more invariably is found to guide to truth, could not be disproved. Whatever experiments on decapitated animals were appealed to, in support of the doctrine that the Brain contains the only seat of sensibility, could be met by a simple denial that the Spinal Cord is everywhere as destitute of that endowment as it appears to be in Man. The cases of profound sleep and apoplexy might be cited as examples of reflex action without consciousness; but these have been met by the assertion, that in such conditions sensations are *felt,* though they are not *remembered.* It is difficult, however, to apply such an explanation to the case of anencephalous human infants (in which all the ordinary reflex actions have been exhibited, with an entire absence of brain), without supposing that the Medulla Oblongata is the seat of a sensibility which we know that the lower part of the Spinal Cord does not possess; and of this there is no evidence whatever.—Experiments on the lower animals, then, and observation of the phenomena manifested by apoplectic patients and anencephalous infants, *might* lead to the conclusion, that the Spinal Cord does not itself possess sensibility, and that its reflex actions are independent of sensation. At this conclusion, Unzer, Prochaska, Sir G. Blane, Flourens, and other physiologists, had arrived; but it was not until special attention was directed to the subject by Dr. M. Hall, that facts were obtained by which a positive statement of it could be supported. For the question might have been continually asked,—If the Spinal Cord in Man be precisely analogous in function to that of the lower Vertebrata, why are not its reflex phenomena manifested, when a portion of it is severed from the rest by disease or injury? The answer to this question is twofold. In the first place, simple division of the cord with a sharp instrument leaves the separated portion in a state of much more complete integrity, and therefore in a state much more fit for the performance of its peculiar functions, than it ordinarily is after disease or violent injury; and as the former method of division is one with which the Physiologist is not likely to meet in Man as a result of accident, and which he cannot experimentally put in practice, the cases in which reflex actions would be manifested are likely to be comparatively few. But, secondly, a sufficient number of such instances *have* now been accumulated, to prove that the occurrence is by no means so rare as might have been supposed; and that nothing is required but patient observation, to throw a great light on this

interesting question, from the phenomena of disease. A most valuable collection of such cases, occurring within his own experience, has been published by Dr. W. Budd;* and the leading facts observed by him will be now enumerated.

707. In the first case, paraplegia was the result of angular distortion of the spine in the dorsal region. The sensibility of the lower extremities was extremely feeble, and the power of voluntary motion was almost entirely lost. "When, however, any part of the skin is pinched or pricked, the limb that is thus acted on jumps with great vivacity; the toes are retracted towards the instep, the foot is raised on the heel, and the knee so flexed as to raise it off the bed; the limb is maintained in this state of tension for several seconds after the withdrawal of the stimulus, and then becomes suddenly relaxed." "In general, while one leg was convulsed, its fellow remained quiet, unless stimulus was applied to both at once." "In these instances, the pricking and pinching were perceived by the patient; but *much more violent* contractions are excited by a stimulus, of *whose presence he is unconscious.* When a feather is passed lightly over the skin, in the hollow of the instep, as if to tickle, convulsions occur in the corresponding limb, much more vigorous than those induced by pinching or pricking; they succeed one another in a rapid series of jerks, which are repeated as long as the stimulus is maintained." "When any part of the limb is irritated in the same way, the convulsions which ensue are very feeble, and much less powerful than those induced by pricking or pinching." "Convulsions, identical with those already described, are at all times excited by the acts of defecation and micturition. At these times, the convulsions are much more vigorous than under any other circumstances, insomuch that the patient has been obliged to resort to mechanical means to secure his person while engaged in these acts. During the act of expulsion, the convulsions succeed one another rapidly, the urine is discharged in interrupted jets, and the passage of the fæces suffers a like interruption." The convulsions are more vigorous, the greater the accumulation of urine; and involuntary contractions occur whenever the bladder is distended, and also when the desire to relieve the rectum is manifested. "In all these circumstances, the convulsions are perfectly involuntary; and he is unable, by any effort of the will, to control or moderate them." The patient subsequently regained, in a gradual manner, both the sensibility of the lower extremities, and voluntary power over them; and as voluntary power increased, the susceptibility to involuntary movements, and the extent and power of these diminished.—This case, then, exhibits an increased tendency to perform reflex actions, when the control of the brain was removed; and it also shows that a slight impression upon the surface, of which the patient was not conscious, was more efficacious in exciting reflex movements, than were others that more powerfully affected the sensory organs.—It should be added that, in the foregoing case, the nutrition of the lower extremities was not impaired, as in most cases of paraplegia; the rationale of this phenomenon, which is to be constantly observed when the reflex actions of the part remain entire, will be understood by reference to § 325.

708. In another case, the paralysis was more extensive, having been

* "Medico-Chirurgical Transactions," vol. xxii.

produced by an injury (resulting from a fall into the hold of a vessel) at the lower part of the neck. There was at first a total loss of voluntary power over the lower extremities, trunk, and hands; slight remaining voluntary power in the wrists, rather more in the elbows, and still more in the shoulders. The intercostal muscles did not participate in the movements of respiration. The sensibility of the hands and feet was greatly impaired. There were retention of urine, and involuntary evacuation of the fæces. Recovery took place very gradually; and during its progress, several remarkable phenomena of reflex action were observed. At first, tickling one sole excited to movement that limb only which was acted upon; afterwards, tickling either sole excited both legs, and, on the 26th day, not only the lower extremities, but the trunk and other extremities also. Irritating the soles, by tickling or otherwise, was at first the only method, and always the most efficient one, by which convulsions could be excited. From the 26th to the 69th day, involuntary movements in all the palsied parts continued powerful and extensive, and were excited by the following causes: in the lower extremities only, by the passage of flatus from the bowels, or by the contact of a cold urinal with the penis; convulsions in the upper extremities and trunk, attended with sighing, by plucking the hair of the pubes. On the 41st day, a hot plate of metal was applied to the soles, and found a more powerful excitor of movement than any before tried. The movements continued as long as the hot plate was kept applied; but the same plate, at the common temperature, excited no movements after the first contact. The contact was distinctly felt by the patient; but *no sensation of heat* was perceived by him, although the plate was applied hot enough to cause vesication. At three different intervals, the patient took one-eighth of a grain of strychnia three times a day. Great increase of susceptibility to involuntary movements immediately followed, and they were excited by the slightest causes. No convulsions of the upper extremities could ever be produced, however, by irritating their integument; though, under the influence of strychnia, pulling the hair of the head, or tickling the chin, would occasion violent spasmodic actions in them. Spontaneous convulsions of the palsied parts, which occurred at other times, were more frequent and more powerful after the use of strychnia. On the first return of voluntary power, the patient was enabled to restrain in some measure the excited movements; but this required a distinct effort of the will; and the first attempts to walk were curiously affected, by the persistence of the susceptibility to excited involuntary movements. When he first attempted to stand, the knees immediately became forcibly bent under him; this action of the legs being excited by contact of the soles with the ground. On the 95th day this effect did not take place, until the patient had made a few steps; the legs then had a tendency to bend-up, a movement which he counteracted by rubbing the surface of the belly: this rubbing excited the extensors to action, and the legs became extended with a jerk. A few more steps were then made; the manœuvre repeated, and so on. This susceptibility to involuntary movements from impressions on the soles, gradually diminished; and on the 141st day, the patient was able to walk about, supporting himself on the back of a chair which he pushed before him; but his gait was unsteady, and much resembled that of chorea. Sensation improved very slowly: it was on the 53rd day that

he first slightly perceived the heat of the metal plate.—Now in this case, the abolition of common sensation was not so complete as in the former instance; but of the peculiar kind of impression, which was found most efficacious in exciting reflex movements, *no consciousness whatever was experienced.* Not less interesting was the circumstance, that convulsions could be readily excited by impressions on surfaces *above* the seat of injury: as, by pulling the hair of the scalp, a sudden noise, and so on. This proves two important points: first, that a lesion of the cord may be such as to intercept the transmission of voluntary influence, and yet may allow the transmission of that reflected from incident nerves. Secondly, that all influences from impressions on incident nerves are diffused through the cord; for, in the instance adduced, the reflected influence was undoubtedly not made to deviate into the cord by the morbid condition of that organ, but followed its natural course of diffusion, being rendered manifest in this case by the convulsions which were excited, in consequence of increased activity of the motor function of the cord. It is further interesting to remark, that, in the foregoing case, the reflex actions were very feeble during the first seven days, in comparison with their subsequent energy; being limited to slight movements of the feet, which could not always be excited by tickling the soles. In another case of very similar character, it was three days after the accident, before any reflex actions could be produced. It is evident, then, that the spinal cord must have been in a state of concussion, which prevented the manifestation of its peculiar functions, so long as this effect lasted; and it is easy, therefore, to perceive, that a still more severe shock might permanently destroy its power, so as to prevent the exhibition of any of the phenomena of reflex action.

709. So many cases of this kind have now occurred, that it may be considered as a demonstrated fact, that the Spinal Cord, or insulated portions of it, may serve in Man, no less than in the lower animals, as the centre of very energetic reflex actions, when the Encephalic power which ordinarily operates through it is suspended or destroyed, or when it is prevented from influencing the Spinal nerves by such an injury to the Cord above their points of connection with it, as prevents the transmission of nervous polarity: and it is further evident that these movements are not more dependent upon sensation, than they are upon the will, since they may be excited without the consciousness of the individual, even when this is fully directed to the part.* And we thus have adequate ground for the assertion, that the movements which may be called forth by stimulation in the states of profound Sleep or Coma, are not to be held to indicate that sensation is even momentarily excited; since we know that the reflex power of the Spinal Cord may be called into action by impressions which do not travel onwards to the sensorium, or which are powerless to affect the consciousness even when they arrive there. These reflex actions of the Spinal Cord have much more regularity and

* The Author is informed by his friend Mr. Paget, that among the notes left by John Hunter (which furnished some of the materials for the admirable Catalogue of the Pathological portion of the Hunterian Museum drawn up by Mr. Paget), there was the record of a case of paraplegia, in which it appeared that Hunter had witnessed reflex movements of the legs in which sensation did not participate. When the patient was asked whether *he felt* the irritation by which the motions were excited, he significantly replied—glancing at his limbs,—"No, Sir, but you see *my legs* do."

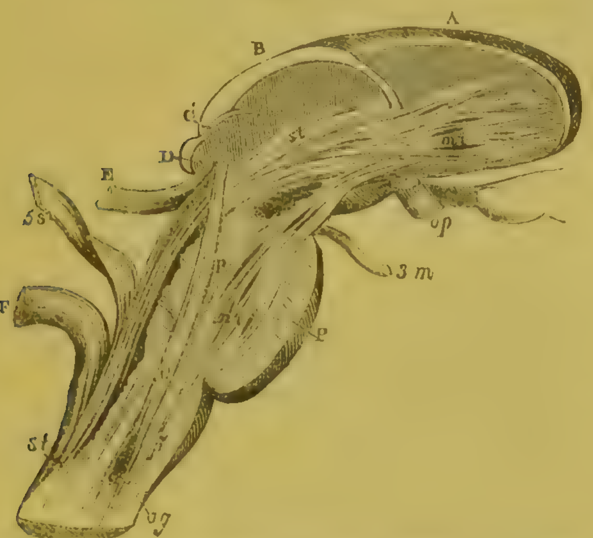
apparent *purposiveness* in the lower Vertebrata, approaching in this respect to the reflex actions of the ganglionic column of Articulata, than they have in Man. For we see that when a portion of *his* Spinal Cord is withdrawn from the influence of the Cerebrum, the reflex actions that may be excited in the limbs with which it has nervous connection, are disorderly and purposeless in their character, notwithstanding that they may be powerful; whilst, on the other hand, if a Frog be decapitated, its body is still supported on its limbs in the usual position, and will recover this if it be disturbed; irritation of the feet will cause it to leap; tickling the cloaca with a probe will excite efforts to push away the instrument; in fact, the movements altogether show almost as much adaptiveness and regularity, as if the mind of the animal were engaged in directing them. It would seem absurd, however, to attribute any psychical agency to the Spinal Cord; since, to remove these movements from the category of *automatic* actions, we must attribute to that organ a power, not merely of feeling, but also of choosing and directing movements with a conscious design; and all our knowledge of the functions of the Nervous System tends to the belief, that such attributes belong only to the Brain. Hence, the adaptiveness of the reflex actions performed by many of the lower tribes of animals, can only be held to indicate that a larger share of such adaptation is effected in them by what may be termed the *mechanism* of their nervous centres, and that less is left to voluntary choice and direction, which can only be safely trusted where a considerable amount of Intelligence exists to guide it. That the existence of even the most perfectly adapted combination of different muscular actions, all obviously bearing upon a definite object, does not in itself justify the attributing this combination to a design or voluntary choice in the individual that executes it, is sufficiently proved by the existence of such a combination in various automatic movements, most essential to the maintenance of the organic functions, which are performed with the utmost regularity, not only without our bestowing any volitional effort upon them, but also under circumstances which indicate that not even our consciousness has any share in developing or directing them. Such are the ordinary and extraordinary movements of Respiration, the movements of Deglutition and Defecation, &c.

710. *Medulla Oblongata.*—The cranial prolongation of the Spinal cord, which is distinguished by this appellation, has been regarded by some Physiologists as the peculiar seat of vitality; since, although the other Encephalic masses may be withdrawn from above, and nearly the whole of the Spinal Cord may be removed from below, without the destruction of life, yet a complete stop is put to the current of vital action when the Medulla Oblongata is destroyed. But the dependence of the vital activity of the body generally upon the functional integrity of this part of the nervous system, is simply consequent upon the fact, that the Medulla Oblongata contains the ganglionic centre of the Respiratory movements; upon the continuance of which, as already shown (CHAP. X. Sect. 3), the continuance of the Circulation is dependent, and, with this, the maintenance of the Organic functions generally. In no other essential respect does the Medulla Oblongata differ from the Medulla Spinalis, than in its ministration to certain classes of reflex movements which are specially destined to afford the conditions requisite for the performance of the functions of

Respiration and Deglutition, instead of exerting its reflex power in the ordinary locomotive actions of the body; but the arrangement of its fibrous strands and of its nuclei of grey matter is peculiar; and a brief notice of its structure, and of the connections of its parts, is consequently desirable.—Four principal strands of nerve-fibres may be distinguished in each of its lateral halves; these are,—I. The Anterior Pyramids or *Corpora Pyramidalia;* II. The Olivary Bodies, or *Corpora Olivaria;* III. The Restiform Bodies, or *Corporia Restiformia;* otherwise called *Processus a Cerebello ad Medullam Oblongatam;* IV. The Posterior Pyramids, or *Corpora Pyramidalia Posteriora.*—The connections of these with the Brain above, and with the Spinal Cord below, will be presently traced.* The vesicular substance, on the other hand, is principally aggregated in three pairs of ganglionic centres; of which the *anterior* forms the nucleus of the Olivary body, the *lateral* of the Restiform, and the *posterior* of the Posterior Pyramidal.

711. The *Anterior Pyramids* (I) consist entirely of fibrous structure, and establish a communication between the 'motor tract' (Fig. 131 *m t*) of the Crura Cerebri, and the anterior and antero-lateral columns of the Spinal Cord. The principal part of their fibres decussate; and these, as they pass from above downwards, dip away from the anterior surface of the Cord, and connect themselves with its *middle* or *lateral* columns, instead of with its anterior, as was pointed out by Rosenthal,† and more fully described by Dr. J. Reid.‡ A small part of the fibres of the pyramidal columns, however, do not decussate, but proceed downwards on the same

Fig. 131.




Dissection of the *Medulla Oblongata*, to show the connections of its several strands:—A, corpus striatum; B, thalamus opticus; C, D, corpora quadrigemina; E, commissure connecting them with the cerebellum; F, corpora restiformia; P, P, pons varolii; *st, st*, sensory tract; *mt, mt*, motor tract; *g*, olivary tract; *p*, pyramidal tract; *og*, olivary ganglion; *op*, optic nerve; 3 *m*, root of the third pair (motor); 5 *s*, sensory root of the fifth pair.

* Great diversities will be found in the accounts given of those connections by different authors; some of which are attributable to a variation in the use of terms, which must not pass unnoticed. By the majority of Anatomists, the name of Corpora Restiformia is given to the *Cerebellar* Columns; and this designation, therefore, it seems advisable to retain. Some, however, and amongst them Dr. J. Reid, in his very excellent description of the Anatomy of the Medulla Oblongata ("Edinb. Med. and Surg. Journal," Jan. 1841), give that name to the columns that pass up from the posterior division of the spinal cord into the crus cerebri —which are here called (after Sir C. Bell) the posterior pyramids; and apply the terms Posterior Pyramids to the Cerebellar column. The truth is that, as Sir C. Bell has justly observed, *all* the tracts of fibrous matter connecting the Brain with the Spinal Cord, have a somewhat *pyramidal* form; and it might be added that all have something of a *restiform* or cord-like aspect.

† "Ein Beitrag zur Encephalatomie," Weimar, 1815.

‡ "Edinb. Med. and Surg. Journ.," Jan. 1841; and "Physiol., Pathol., and Anat. Researches," CHAP. VII.

side, into the corresponding *anterior* columns of the Spinal Cord.—II. The *Olivary* bodies are composed of fibrous strands, enclosing a grey nucleus (Fig. 131, *og*) on either side. The upward continuation of the former divides, while passing through the Pons Varolii, into two bands, one of which proceeds upwards and forwards as a part of the 'motor tract' (*m t*) of the Crus Cerebri, whilst the other (*o*) proceeds upwards and backwards to reach the Corpora Quadrigemina (C, D). The olivary columns are continuous inferiorly with the *anterior* columns of the Spinal Cord; and afford attachments to the anterior roots of the 1st and 2nd cervical nerves. The vesicular nucleus, which is known as the *corpus dentatum*, seems to be especially connected with the origins of the nerves concerned in the regulation of the movements of the tongue; thus we find that anteriorly a portion of the roots of the Hypoglossal, which is the motor nerve of the tongue, issue from it; whilst posteriorly a portion of the roots of the Glosso-pharyngeal, which is one of the sensory nerves of that organ, seem to terminate in it.—III. The *Restiform* bodies, in like manner, each consist of fibrous strands (F) enclosing a grey nucleus. The fibrous strands pass upwards into the Crura Cerebelli; whilst below they are chiefly continuous with the *posterior* columns of the Spinal Cord, having also some connection with the posterior part of the *middle* columns. These Cerebellar columns also communicate, however, with the *anterior* columns of the Spinal Cord, by a band of 'arciform' fibres, whose connections were first distinctly described by Mr. Solly;* of these there is a superficial set which unites itself with the pyramidal columns, and a deep set which comes into relation with the olivary. Their grey nucleus, or 'restiform ganglion,' appears to be the ganglionic centre of the Pneumogastric nerves, and of a portion of the roots of the Glossopharyngeal.—IV. The *Posterior Pyramids* are scarcely distinguishable externally from the Restiform bodies, of which they were formerly described as a constituent part; they, however, form the immediate boundaries of the posterior median fissure; and whilst superficially marked-off from the Restiform bodies by a slight groove, are more completely separated from them by their anatomical relations to the parts above and below. Their fibres establish a connection between the sensory tract (*st, st*) of the Crura Cerebri, and the posterior part of the *lateral* columns of the Spinal Cord, some of them passing also into its posterior columns. These fibrous tracts are stated by Mr. Solly † and Dr. Radclyffe Hall ‡ to decussate, partially at least, whilst passing through the Pons Varolii.§ The grey nuclei of the Posterior Pyramids, situated immediately beneath the 'fourth ventricle' (which is nothing else than the space left by the divergence of the Restiform and Posterior-Pyramidal tracts), are the ganglionic centres of the Auditory nerves, or the proper *Auditory ganglia;* and it is interesting to observe that their seat precisely corresponds with that of the rudimental organ of hearing in many Invertebrata.

* "Philosophical Transactions," 1836.

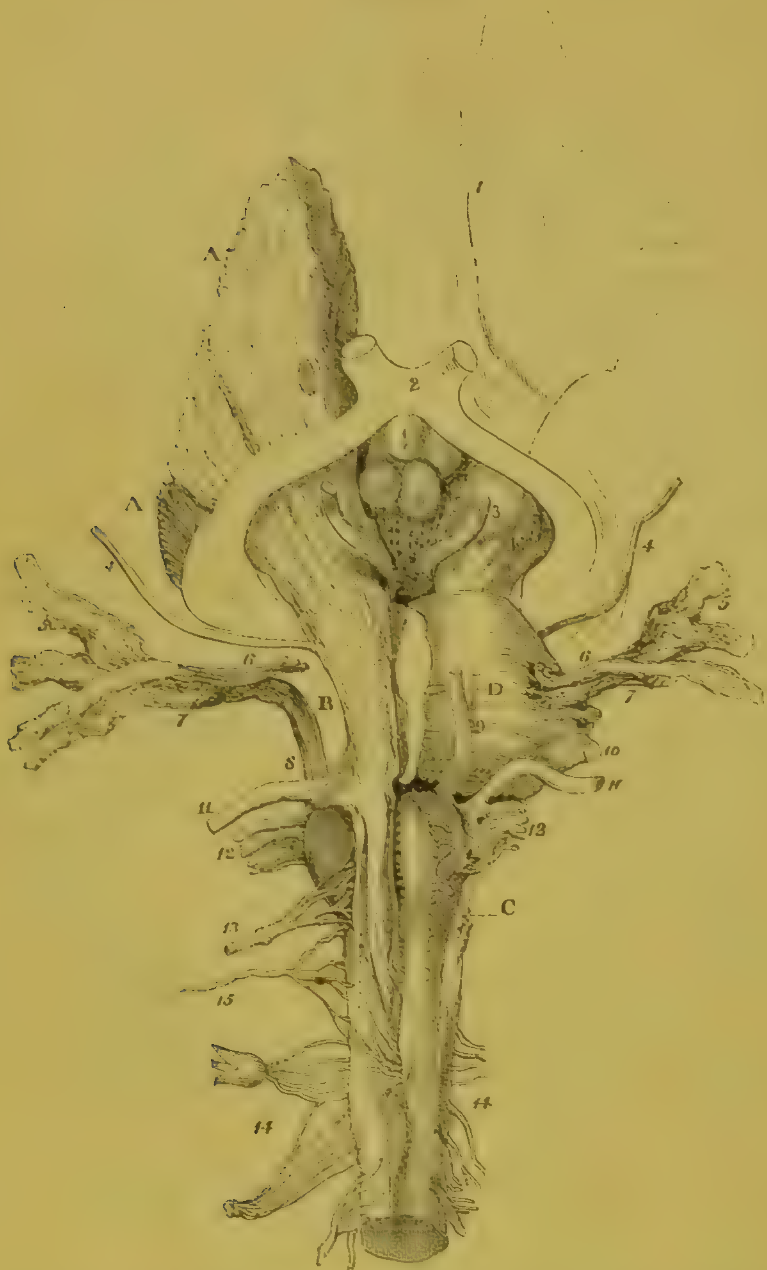
† "The Human Brain," 2nd edit., p. 243.

‡ "Edinb. Med. and Surg. Journ.," July, 1847, Plate VII.

§ A decussation of the Posterior Pyramids was described by Sir C. Bell as occurring at the same level with the decussation of the Anterior Pyramids (Fig. 133, c); there can be no doubt, however, that this is an error, which probably originated in his having misinterpreted the appearance presented by the posterior aspect of the anterior decussation.

712. The Medulla Oblongata is usually considered as terminating at the lower border of the Pons Varolii; but it will be convenient here to trace upwards the strands by which it is connected with the higher Ence-

FIG. 132.




Course of the *Motor tract*, according to Sir C. Bell.—A, A, fibres of the Hemispheres, converging to form the anterior portion of the crus cerebri; B, the same tract, where passing the crus cerebri; C, the right Pyramidal body, a little above the point of decussation; D, the remaining part of the Pons Varolii, a portion having been dissected off to expose B.—1, olfactory nerve, in outline; 2, union of optic nerves; 3, 3, motor oculi; 4, 4, patheticus; 5, 5, trigeminus; 6, 6, its muscular division; 7, 7, its sensory root: 8, origin of sensory root from the posterior part of the medulla oblongata; 9, abducens oculi; 10, auditory nerve; 11, facial nerve; 12, eighth pair; 13, hypoglossal; 14, spinal nerves; 15, spinal accessory of right side, separated from par vagum and glosso-pharyngeal.

phalic centres, as a clearer idea of its anatomical and physiological relations will thus be obtained.—The Pons is chiefly composed of transverse

fibres which constitute the great commissure of the Cerebellum; and these fibres not only *surround* the longitudinal bands which connect the Cerebral mass with the Spinal Cord, but *pass through* them; so as in some degree to isolate the two lateral halves from one another, and to form a complete septum between the anterior and posterior portions of each. These *anterior* and *posterior* tracts of the Crura Cerebri are respectively subservient to the *motor* and the *sensory* functions; as is clearly indicated by the endowments of the nerves which are connected with each.*—The *Motor* tract is brought into view, by simply raising the superficial layer of the Pons, and tracing upwards and downwards the longitudinal fibres which then present themselves. It is then found, that these fibres may be traced *upwards* into the Corpora Striata; and *down-*

FIG. 133.


Course of the *Sensory tract* according to Sir C. Bell.—A, Pons Varolii; B, B, sensory tract separated; C, union of posterior columns; D, D, posterior roots of spinal nerves; E, sensory roots of fifth pair.

*wards* into the Anterior Pyramids and a portion of the Olivary columns; so that they connect the Corpora Striata with the *anterior* and with the anterior portion of the *lateral* columns of the Spinal Cord. With this tract we find connected—passing from below upwards—the roots of the Spinal Accessory, the Hypoglossal, the Facial or Portio Dura of the 7th, the 6th or Abducens oculi, the smaller root of the 5th (which can be traced to the part of the Olivary column that passes upwards to the Corpora Quadrigemina), the 4th or Trochlearis (which is attached to the same part of the tract), and the 3rd or Oculo-motor nerves; all of which are purely motor in their endowments.—The *Sensory* tract is displayed, by opening the Medulla Oblongata on its posterior aspect; and then sepa-

* This was first clearly shown by Sir C. Bell in the "Philos. Transact.," 1835.

rating and turning aside the Restiform columns, so as to bring into view the posterior pyramids. Its fibres may be traced *upwards* into the Thalami Optici; whilst they pass, through the Posterior Pyramids, into the posterior portion of the *lateral* columns, and also into the *posterior* columns of the Spinal Cord. With this tract are connected nearly the whole of the roots of the Pneumogastric and Glosso-pharyngeal nerves, and the larger or sensory root of the 5th pair.—The greater part of the Motor tract decussates where the Anterior Pyramids become continuous with the lateral columns of the Spinal Cord; on the other hand, the greater part of the Sensory tract decussates in its passage through the Pons Varolii.—The following tabular view may assist in conveying a knowledge of this somewhat intricate piece of Anatomy; which, when once mastered, will be found to be really simpler than it appears.

| SPINAL CORD. | MEDULLA OBLONGATA. | BRAIN. |
|---|---|---|
| | *Anterior or Motor Division.* | |
| Anterior Columns | Arciform fibres of Olivary and Anterior Pyramidal columns | Cerebellum. |
| | Posterior portion of Olivary columns . . . . | Corpora Quadrigemina. |
| | Anterior portion of Olivary columns . . . | Corpora Striata. |
| | Non-decussating portion of Anterior Pyramidal columns | |
| Anterior portion of Lateral Columns | Decussating portion of Anterior Pyramidal columns . | |
| | *Posterior or Sensory Division.* | |
| Posterior portion of Lateral Columns | Decussating portion (?) of Posterior Pyramidal columns | Thalami Optici. |
| Posterior Columns | Non-decussating portion (?) of Posterior Pyramidal columns | |
| | Restiform columns . . . . . . . | Cerebellum. |

713. *Nerves of the Spinal Axis.*—With the Spinal Cord (in its limited sense) there are connected thirty-one pairs of nerves; each of these corresponding to a vertebral segment of the body, and having a double set of roots, as already described (§ 696). The anterior roots are usually the smaller; and this is particularly the case with those of the cervical nerves, in which the posterior roots are of remarkable comparative size. In the 1st Cervical or 'sub-occipital' pair, the anterior roots are sometimes wanting; but there is then a derivation of fibres from the Spinal Accessory, or from the Hypoglossal, or from both. The two roots of the ordinary Spinal nerves unite immediately beyond the ganglion, which is situated on the posterior one; and the trunk thus formed separates immediately into two divisions,—the anterior and posterior,—each of which contains both afferent and motor fibres. These divisions, of which the anterior is by far the larger, proceed to the anterior and posterior parts of the body respectively; and are chiefly distributed to the skin and the muscles. The anterior branch is that which communicates with the Sympathetic nerve.—In addition to these, however, the cranial prolongation of the Spinal Axis is the centre of all the cephalic nerves, save those of special sensation, which terminate in their respective ganglia; and as these cephalic nerves are for the most part distinguished by the peculiarity of their endowments, they require to be separately noticed.

714. The pair of nerves commonly designated as the *Fifth* of the Cephalic series, or as the *Trigeminus*, is the one which more nearly re-

sembles the ordinary Spinal nerves (as was long since pointed out by Sir C. Bell), than does any other of those originating within the cranium. It possesses two distinct sets of roots, of which one is much larger than the other; on the larger root, as on the posterior and larger root of the Spinal nerves, is a distinct ganglion; and the fibres arising from the smaller root do not blend with the others, until after the latter have passed through this ganglion. The trunk of the nerve separates, as is well known, into three divisions,—the Ophthalmic, the Superior Maxillary, and the Inferior Maxillary; and it can be easily shown, by careful dissection, that the fibres of the smaller root pass into the last of these divisions alone. When the distribution of this nerve is carefully examined, it is found that the first and second divisions of it proceed almost entirely to the skin and mucous surfaces, only a very small proportion of their fibres being lost in the muscles; whilst of the branches of the third division, a large number are distinctly muscular. Hence analogy, and the facts supplied by anatomical research, would lead to the conclusion, that the first two divisions are nerves of sensation only, and that the third division combines sensory and motor endowments. Such an inference is fully borne out by experiment. When the whole trunk is divided within the cranium by the penetration of a sharp instrument (which Magendie, by frequent practice, has been able to accomplish), evident signs of acute pain are given. After the incision has been made through the skin, the animal remains quiet until the nerve is touched; and when it is pressed or divided, doleful cries are uttered, which continue for some time, showing the painful effect of the irritated state of the cut extremity. The common sensibility of all the parts supplied by this nerve is entirely destroyed on the affected side. The jaw does not hang loosely, because it is partly kept up by the muscles of the other side; but it falls in a slight degree; and its movements are seen, when carefully observed, to be somewhat oblique. If the trunk be divided on each side, the whole head is deprived of sensibility; and the animal carries it in a curious vacillating manner, as if it were a foreign body.—If the anterior or *Ophthalmic* branch only be divided, all the parts supplied by it are found to have lost their sensibility, but their motions are unimpaired; and all experiments and pathological observations concur in attributing to it sensory endowments only. The only apparent exception is in the case of the naso-ciliary branch, since there is good reason to believe that the long root of the ciliary ganglion and the long ciliary nerves possess motor powers; but these appear to be derived from the Sympathetic or from the 3rd pair. When the whole nerve, or its anterior branch, is divided in the rabbit, the pupil is exceedingly contracted, and remains immovable; but in dogs and pigeons it is dilated. The pupil of the other eye is scarcely affected; or, if its dimensions be changed, it soon returns to its natural state. The eyeball, however, speedily becomes inflamed; and the inflammation usually runs on to suppuration and complete disorganization. The commencement of these changes may be commonly noticed within twenty-four hours after the operation; and they appear to be due to the want of the protective secretion, which (as will be explained when the direct influence of the nervous system upon the organic functions is considered) is necessary to keep the mucous surface of the eye in its healthy condition, and which is not formed when the sensibility of that surface

is destroyed.—The *Superior Maxillary* branch, considered in itself, is equally destitute of motor endowments with the ophthalmic; but its connections with other nerves, through the spheno-palatine ganglion and its anastomosing twigs, may introduce a few motor fibres into it.—The *Inferior Maxillary* branch is the only one which possesses motor as well as sensory endowments from its origin; but its different subdivisions possess these endowments in varying proportions, some being almost exclusively motor, and others as completely of a sensory character. The latter is probably the nature of the Lingual branch; and there seems good reason to believe, as will hereafter be shown (§ 717), that this ministers not only to the tactile sensibility of the tongue, but to the sense of Taste. The muscles put in action by this division are solely those concerned in the masticatory movements.—The 5th pair is connected, in different parts of its course, with a number of small ganglia belonging to the Sympathetic system. One of the most interesting of these ganglia is the *Ophthalmic* or *Ciliary* (Fig. 134), which is the centre whence the eyeball derives its supply of nerves, sensory, motor, and sympathetic. This ganglion derives its sensory fibres by its 'long root' from the nasal branch of the Ophthalmic division of the 5th pair; its motor fibres, by the 'short root,' from the 3rd pair; whilst by another small root it is connected with the cavernous plexus of the Sympathetic system;—thus presenting a sort of miniature representation of the entire series of Sympathetic ganglia, and of their connections with the Cerebro-spinal system.*

715. The *Third*, *Fourth*, and *Sixth* pairs, together make up the apparatus of motor nerves, by which the muscles of the Orbit are called into action. The 3rd pair supplies the greater number of the muscles; the 4th being confined to the Superior Oblique, and the 6th to the External Rectus. Of these nerves, the 3rd pair is the only one which exhibits any appearance of sensibility, when its trunk is irritated; but this sensi-

* The functions of this ganglion have been made the subject of particular investigation by Dr. C. Radclyffe Hall ("Edinb. Med. and Surg. Journal," 1846–48), whose most important results are as follows:—

1. The size of the ciliary ganglion is always in direct proportion to the activity of the iris, which in turn always bears a direct relation to the strength and acuteness of vision, and to the nocturnal habits of the animal, and implies a proportionate development of the internal vascular apparatus of the eye.

2. The ganglion is always more intimately connected with the 3rd pair than with any other, the size of the short root being always in direct relation to that of the ganglion; and the ganglion being sometimes a mere swelling on the trunk of the nerve.

3. The fibres derived from the 5th pair do not terminate in the ganglion, but pass onwards through it to the ciliary plexus.

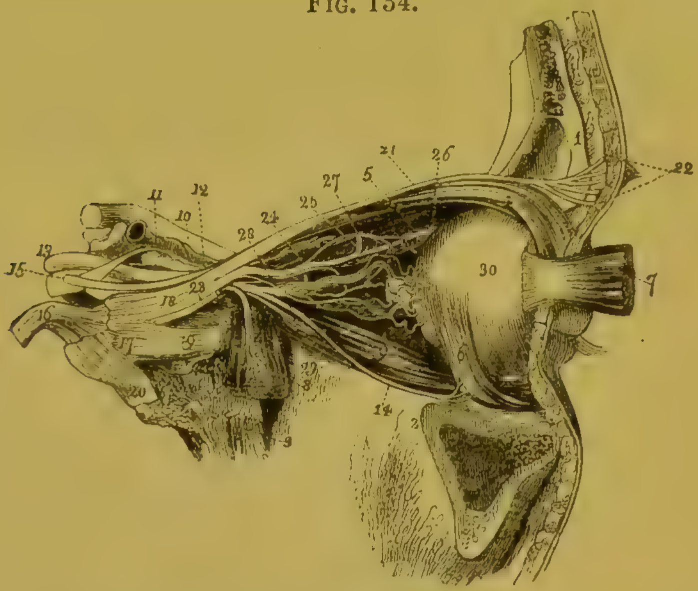
4. In the Rabbit, the iris receives fibres from the 6th pair which do not pass through the ganglion; and it is through this that the contraction of the pupil is produced in that animal by irritation of the 5th pair, which will not produce any effect upon the pupil of the Dog, Cat, or Pigeon, so long as it does not affect the brain to the extent of producing vertigo, nor affect the visual sense in any other way.

5. Irritation of the 5th nerve does not in any animal affect the action of the iris *after* the division of the cerebral connections of all the other ocular nerves; so that its influence over the movements of the iris must be reflected through the encephalic centres, not through the ophthalmic ganglion.

6. The function of the ganglionic centre itself, as a part of the Sympathetic system, is to bring the "organic actions" of the eyeball, especially its supply of blood, into harmony with its functional activity; this harmony being produced by the passage of the cerebro-spinal nerves through the ganglion, which excites the synergetic action of its own vesicles and nerve-fibres.

bility is not nearly so great as that of the 5th pair; and as there is no reason to believe that it is really possessed by the 3rd in virtue of its direct connection with the nervous centres, it is probably imparted by the anastomosis of that nerve with the 5th,—some filaments of which may pass backwards as well as forwards, so as to confer sensibility on the

FIG. 134.



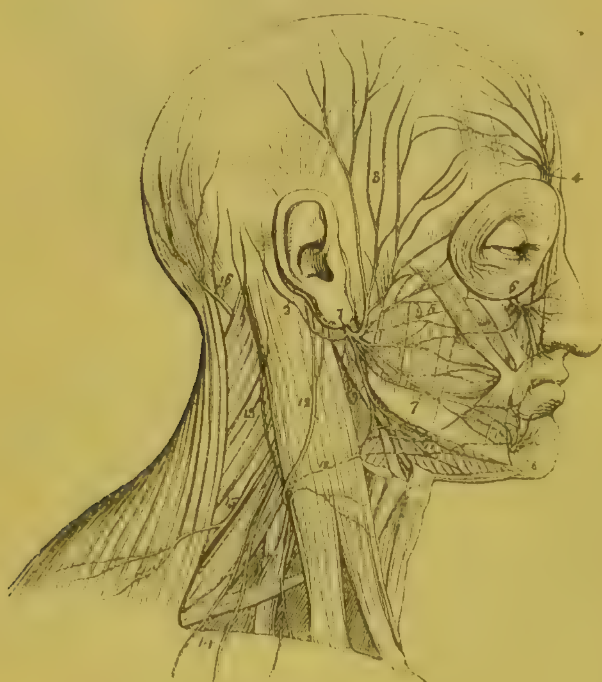
The *Nerves of the Orbit* seen from the outer side: after Arnold.—1. Section of the frontal bone; immediately behind the numeral is the frontal sinus, and, in front, the integument. 2. The superior maxillary bone; the section in front of the numeral exhibits the maxillary sinus. 3. Part of the sphenoid bone. 4. The levator palpebræ and superior rectus muscles. 5. The superior oblique muscle. 6. The inferior oblique muscle. 7. The ocular half of the external rectus muscle drawn forwards. 8. The orbital half of the external rectus muscle turned downwards. On this muscle the sixth nerve is seen dividing into branches. 9. The inferior rectus muscle. 10. The optic nerve. 11. The internal carotid artery emerging from the cavernous sinus. 12. The ophthalmic artery. 13. The third nerve. 14. The branch of the third nerve to the inferior oblique muscle. Between this and the sixth nerve (7) is seen the branch which supplies the inferior rectus; its branch to the ophthalmic ganglion is seen proceeding from the upper side of the trunk of the nerve, at the bottom of the orbit. 15. The fourth nerve. 16. The trunk of the fifth nerve. 17. The Casserian ganglion. 18. The ophthalmic nerve. 19. The superior maxillary nerve. 20. The inferior maxillary nerve. 21. The frontal nerve. 22. Its division into branches to supply the integument of the forehead. 23. The lachrymal nerve. 24. The nasal nerve; the small nerve seen in the bifurcation of the nasal and frontal nerve, is one of the branches of the upper division of the third nerve. 25. The nasal nerve passing over the internal rectus muscle to the anterior ethmoidal foramen. 26. The infra-trochlear nerve. 27. A long ciliary branch of the nasal; another long ciliary branch is seen proceeding from the lower aspect of the nerve. 28. The long root of the ophthalmic ganglion, proceeding from the nasal nerve, and receiving the sympathetic root which joins it at an acute angle. 29. The ophthalmic ganglion, giving off from its fore-part the short ciliary nerves. 30. The globe of the eye.

trunk of the 3rd, above as well as beyond their point of entrance.—The peculiar mode in which those motor nerves ordinarily excite the muscles to action, under the guidance of the visual sense, will be considered in the next Section. Although commonly ranked as cephalic nerves, they have no direct connection with the Cerebrum; their real origin being from the upper part of the Spinal Axis (§ 712). The roots of the 3rd pair may be traced into direct connection with the Corpora Quadrigemina; a fact of considerable physiological importance, as will hereafter appear.—The chief actions of a purely *reflex* nature, to which this group of nerves ordinarily ministers, are the government of the diameter of the pupil, which is accomplished through the Third pair; and the rolling of the eyeball beneath the upper lid during sleep, as well as in the efforts of sneezing, coughing, &c. But irregular movements of the eyeballs

which must be referred to the same group, are continually seen to accompany various other forms of convulsive action.

716. The *Portio Dura* of the *Seventh* pair, or *Facial* nerve, has been considered, since the first researches of Sir C. Bell, to be a nerve of motion only; but some physiologists have maintained, that it both possesses sensory endowments, and arises by a double root. According to Valentin, however, who experimented on the roots exposed within the cranium, it possesses no sensory endowments at its origin; since, when these roots were touched, the animals gave no signs of pain, though violent muscular movements were excited in the face. Subsequently to its first entrance into the canal by which it emerges, however, it anastomoses with other

Fig. 135.



The distribution of the *Facial* nerve, and the branches of the Cervical plexus.—1. The facial nerve, escaping from the stylo-mastoid foramen, and crossing the ramus of the lower jaw; the parotid gland has been removed in order to see the nerve more distinctly. 2. The posterior auricular branch; the digastric and stylo-mastoid filaments are seen near the origin of this branch. 3. Temporal branches, communicating with (4) the branches of the frontal nerve. 5. Facial branches, communicating with (6) the infra-orbital nerve. 7. Facial branches, communicating with (8) the mental nerve. 9. Cervico-facial branches, communicating with (10) the superficialis colli nerve, and forming a plexus (11) over the submaxillary gland. The distribution of the branches of the facial in a radiated direction over the side of the face, constitutes the pes anserinus. 12. The auricularis magnus nerve, one of the ascending branches of the cervical plexus. 13. The occipitalis minor, ascending along the posterior border of the sterno-mastoid muscle. 14. The superficial and deep descending branches of the cervical plexus, 15. The spinal accessory nerve, giving off a branch to the external surface of the trapezius muscle. 16. The occipitalis major nerve, the posterior branch of the second cervical nerve.

nerves; and thus *sensory* fibres are introduced into it from many different sources,—anteriorly, from the 5th pair, and posteriorly, from the cervical nerves,—which cause irritation of several of its branches to produce pain. The number and situation of the anastomoses vary much in different animals; so that it is impossible to make any very comprehensive statement in regard to them.—Experimental researches leave no doubt that the Portio Dura is the *general motor* nerve of the face; ministering to the

nfluence of Volition and of Emotion, and also being the channel of the eflex movements concerned in respiration and other automatic actions f the muscles; but not being in the least concerned in the act of nastication.

717. The functions of the *Glosso-Pharyngeal* nerve have been heretofore lluded to in part; but there still remain several questions to be discussed n regard to them. Reasons have been given for the belief, that it is hiefly an afferent nerve,—scarcely having any *direct* power of exciting nuscular contraction, but conveying impressions to the Medulla Oblon-gata, which produce reflex movements of the motor nerves concerned in leglutition (§ 427). This view of its function was deduced by Dr. J. Reid rom minute anatomical investigation, and from a large number of expe-iments. Some experimenters assert, that they have succeeded in excit-ng direct muscular actions through its trunk; but these actions seem to e limited to the stylo-pharyngei and to the palato-glossi muscles.—Much controversy has taken place on the question, whether this nerve is o be regarded as ministering, partly or exclusively, to the sense of Taste; nd many high authorities have ranged themselves on each side. The question involves that of the function of the Lingual branch of the 5th pair; and it is partly to be decided by the anatomical relations of the two nerves respectively. The Glosso-pharyngeal is principally distributed on the mucous surface of the fauces, and on the back of the tongue; but according to Valentin, it sends a branch forwards, on either side, some-what beneath the lateral margin, which supplies the edges and inferior surface of the tip of the tongue, and inosculates with the Lingual branch of the 5th. On the other hand, the upper surface of the front of the tongue is supplied by this Lingual branch. The experiments of Dr. Alcock, whose conclusions are borne out by Dr. J. Reid, decidedly support the conclusion, that the gustative sensibility of *this* part of the tongue is chiefly due to the latter nerve, being evidently impaired by division of it. On the other hand, it is equally certain, that the sense of taste is not destroyed by section of the Lingual nerve on each side; and it seems also well ascertained, that it is impaired by section of the Glosso-pharyngeal nerve.—The pathological evidence bearing upon this point appears some-what contradictory. Numerous cases have been recorded,* in which both common and gustative sensation were destroyed in the parts of the tongue supplied by the 5th pair, when that nerve was paralysed; in some of these, the loss of the sense of taste appeared to extend itself to the base of the tongue, but then there was evidence that the Glosso-pharyngeal was involved in the paralysis. On the other hand, cases of paralysis of the 5th pair are related by Mr. Noble and by Vogt,† in which common sensation was lost, whilst the sense of taste remained in the same parts; and Mr. Noble relates another case,‡ in which there was loss of taste without impairment of common sensation. The cases of Mr. Noble and Vogt would seem to indicate that the 5th pair does not minister to the sense of Taste; but, as Dr. J. Reid has justly observed, we have no evidence

* See especially the cases of Romberg, in "Müller's Archiv.," 1838, heft iii.; Todd and Bowman, in "Physiological Anatomy," vol. i. p. 445; and Dixon, in "Med. Chir. Trans." vol. xxviii.

† "Medical Gazette," Oct. 25, 1834; and "Müller's Archiv.," 1840, p. 72.

‡ "Medical Gazette," Nov. 21, 1835.

Fig. 136.

Origin and distribution of the *Eighth Pair* of nerves.—1, 3, 4. The Medulla Oblongata. 1. The Corpus Pyramidale of one side. 3. The Corpus Olivare. 4. The Corpus Restiforme. 2. The Pons Varolii. 5. The Facial nerve. 6. The origin of the Glosso-pharyngeal nerve. 7. The ganglion of Andersch. 8. The trunk of the nerve. 9. The Spinal Accessory nerve. 10. The ganglion of the Pneumogastric nerve. 11. Its plexiform ganglion. 12. Its trunk. 13. Its pharyngeal branch forming the pharyngeal plexus (14) assisted by a branch from the glosso-pharyngeal (8) and one from the superior laryngeal nerve (15). 16. Cardiac branches. 17. Recurrent laryngeal branch. 18. Anterior pulmonary branches. 19. Posterior pulmonary branches. 20. Œsophageal plexus. 21. Gastric branches. 22. Origin of the Spinal Accessory nerve. 23. Its branches distributed to the sterno-mastoid muscle. 24. Its branches to the trapezius muscle.

that *all* the filaments of the 5th Pair sent to the tongue were affected; and there is believed to be no case on record, in which the whole of the 5th pair, or of its 3rd branch, was found to be diseased after death, and in which during life the sense of Taste had been retained in the anterior and middle parts of the tongue. Hence these cases only serve to indicate what is probable on other grounds; viz., that the filaments which convey gustative impressions are not the same with those that minister to common sensation. — On the whole, then, it seems to be proved by anatomical and experimental evidence, that both the Glosso-pharyngeal and the Fifth pair minister alike to the tactile and to the gustative sense; and there is nothing in the pathological facts just noticed, that militates against this conclusion. There seems good reason to believe the Glosso-pharyngeal to be exclusively the nerve, through which the impressions made by disagreeable substances taken into the mouth are propagated to the Medulla Oblongata, so as to produce nausea and to excite efforts to vomit.

718. The functions of the *Pneumogastric* nerve at its *roots* have been made the subject of particular examination by various experimenters; some of whom (for instance, Valentin, Longet, and Morganti) have concluded that it *there* possesses no motor power, but is entirely a sensory or rather an afferent nerve. According to these, if the roots be carefully separated from those of the Glosso-Pharyngeal, and (which is a matter of some difficulty) from those of the Spinal Accessory nerve, and be then irritated, no movements of the organs supplied by its trunk can be observed: whilst, if the roots be irritated when in connection with the nervous centres, muscular contractions, evidently of a reflex character, result from

he irritation; and strong evidences of their sensibility are also given. t has been further asserted that, when the roots of the Spinal Accessory ierve are irritated, no indications of sensation are given; but that the nuscular parts supplied by the Pneumogastric, as well as by its own runk, are made to contract, even when the roots are separated from the iervous centres; so that these roots must be regarded as the channel of he motor influence, transmitted to them from the Medulla Oblongata. Where the Pneumogastric swells into the jugular ganglion, an interchange of fibres takes place between it and the Spinal Accessory; and it seems clear that the pharyngeal branches, which are among the most decidedly motor of all those given off from the Pneumogastric, may in great part be traced backwards into the Spinal Accessory.—But, on the other hand, an equally numerous and trustworthy set of experimenters (among whom may be mentioned J. Reid, Müller, Volkmann, Stilling, Wagner, and Bernard) are opposed to this opinion; maintaining that the Pneumogastric has motor roots of its own; and affirming that irritation of the roots of the Spinal Accessory produces little or no effect on the muscles supplied by the trunk of the Par Vagum.—The fact appears to be, that the roots of these two nerves are so commingled, that it is difficult to say what belong exclusively to each. Some of the fibres usually considered to belong to the Spinal Accessory are occasionally seen to connect themselves with the roots of the Pneumogastric, even before the ganglion is found upon it. And it seems most probable, that while the roots of the Spinal Accessory are entirely motor, those of the Pneumogastric are *chiefly* afferent; that they inosculate with each other, in a degree which may vary in different species, and even in different individuals; and that the Pneumogastric may thus derive additional motor fibres from the Spinal Accessory, whilst it supplies that nerve with afferent fibres. Further, from the researches of M. Cl. Bernard, to be presently noticed (§ 719), it appears probable that the motor fibres properly belonging to the Pneumogastric are adequate to the regulation of those movements of the larynx and other portions of the air-passages, which are concerned in the *passive* act of Respiration.—In regard to its *trunk*, there can be no doubt that the Pneumogastric is to be considered as a nerve of double endowments; although it is certain that these endowments are very differently distributed amongst its branches. That the nerve is capable of conveying those impressions, which become *sensations* when communicated to the sensorium, is experimentally proved by the fact, that, when its trunk is pinched, the animal gives signs of acute pain: but it is also evident from the painful consciousness we occasionally have, of an abnormal condition of the organs which it supplies. Thus, the suspension of the respiratory movements gives rise to a feeling of the greatest uneasiness, which must be excited by impressions conveyed through this nerve from the lungs; and an inflamed state of the walls of the air-passages causes the contact of cold and dry air to produce distressing pain and irritation. Yet of the ordinary impressions conveyed from these organs, which are concerned in producing the respiratory movements, and in regulating the actions of the glottis, we are not conscious. The same may be said of the portion of the nerve distributed upon the alimentary tube. The pharyngeal branches are almost exclusively motor, the afferent function being performed by the Glosso-pharyngeal; whilst the œsophageal and

gastric are both afferent and motor, conveying impressions which excite reflex movements in the muscles of those parts, but which do not become sensations except under extraordinary circumstances.—The participation of this nerve in the operations of Deglutition, Digestion, Circulation, and Respiration, and the effects of injury to its trunk or branches, have already been considered in the account of those functions.

719. In regard to the functions of the *Spinal Accessory* nerve, also, there has been great difference of opinion; the peculiarity of its origin and course having led to the belief, that some very especial purpose is answered by it. The roots of this nerve arise from the side of the Spinal Cord as low down as the 5th or 6th cervical nerve; and the trunk formed by them ascends into the cranium between the anterior and posterior roots of the spinal nerves. From the recent researches of Mr. J. L. Clarke,* it appears that these roots may be traced into a special tract of vesicular matter, which descends as far as the lumbar enlargement. The predominance of motor fibres in its roots, its inosculation with the Pneumogastric, and its probable reception of sensory fibres from the latter whilst imparting to it motor filaments, have been already referred to (§ 718). As its trunk passes through the foramen lacerum, it divides into two branches; of which the internal, after giving off some filaments that assist in forming the pharyngeal branch of the Pneumogastric, becomes incorporated with the trunk of that nerve; whilst the external proceeds outwards, and is finally distributed to the sterno-cleido-mastoideus and trapezius muscles, some of its filaments inosculating with those of the cervical plexus. When the external branch is irritated, before it perforates the sterno-mastoid muscle, vigorous convulsive movements of that muscle and of the trapezius are produced; and the animal does not give any signs of pain, unless the nerve be firmly compressed between the forceps, or be included in a tight ligature. Hence it may be inferred, that the functions of this nerve are chiefly motor, and that its sensory filaments are few in number. Further, when the nerve has been cut across, or firmly tied, irritation of the lower end is attended by the same convulsive movements of the muscles; whilst irritation of the upper end in connection with the spinal cord, is unattended with any muscular movement. Hence it is clear that the motions occasioned by irritating it are of a direct, not of a reflex character. The same muscular movements are observed on irritating the nerve in the recently-killed animal, as during life.—According to Sir C. Bell, the Spinal Accessory is a purely Respiratory nerve, whose office it is to excite the involuntary or automatic movements of the muscles it supplies, which share in the act of respiration; and he states that the division of it paralyses, as muscles of respiration, the muscles to which it is distributed; though they still perform the voluntary movements, through the medium of the spinal nerves. Both Valentin and Dr. J. Reid, however, positively deny that this is the case; and Dr. Reid's method of experimenting was well adapted to test the truth of the assertion.† The functions of this nerve have been made the subject of special examination

* "Philosophical Transactions," 1851, p. 613.

† "See his "Physiol., Pathol., and Anat. Researches," p. 151; and "Edinb. Med. and Surg. Journ.," Jan., 1838.

M. Cl. Bernard ;* who has arrived at the conclusion that the Spinal ·cessory is a purely motor nerve, whose action is not essential to the .linary movements of respiration, these being provided-for by the Pneu- ›gastric and ordinary Spinal nerves ; but that its special function is to ing the respiratory movements into accordance with the requirements Animal life, adapting the actions of the muscles of the larynx and .orax to the production of *voice*, or to general muscular *effort*. The .ternal branch, which is specially distributed, with the fibres of the ıeumogastric, to the pharynx and larynx, is peculiarly subservient to the rmer of these purposes ; and the external to the latter. This conclu- on is sufficiently in accordance with the results obtained by other expe- menters, to be received as a probable explanation of the facts which ave been observed by them.

720. The *Hypoglossal* nerve, or *Motor Linguæ*, is the only one which, ı the regular order, now remains to be considered. That the distribution f this nerve is restricted to the muscles of the tongue, is a point very ısily established by anatomical research; and accordingly we find that, ›ng before the time of Sir C. Bell, Willis had spoken of it as the nerve of he motions of articulation, whilst to the Lingual branch of the 5th pair ιe attributed the power of exercising the sense of taste; and he distinctly tated, that the reason of this organ being supplied with two nerves, is its ıouble function. The inference that it is chiefly, if not entirely, a *motor* ıerve, which has been founded upon its anatomical distribution, is sup- ›orted also by the nature of its origin, which is usually from a single root, ;orresponding to the anterior root of the Spinal nerves. Experiment .hows that, when the trunk of the nerve is stretched, pinched, or gal- ·anized, violent motions of the whole tongue, even to its tip, are occasioned; ınd also, that similar movements take place after division of the nerve, when the cut end most distant from the brain is irritated. In regard to :he degree in which this nerve possesses sensory properties, there is some difference of opinion amongst physiologists, founded, as it would seem, on a variation in this respect between different animals. Indications of pain ıre usually given, when the trunk is irritated after its exit from the cranium; but these may proceed from its free anastomosis with the cer- vical nerves, which not improbably impart sensory fibres to it. But in some Mammalia, the hypoglossal nerve has been found to possess a small posterior root with a ganglion ; this is the case in the Ox, and also in the Rabbit; and in the latter animal, Valentin states that the two trunks pass out from the cranium through separate orifices, and that, after their exit, one may be shown to be sensory, and the other to be motor. Hence, this nerve, which is the lowest of those that originate in the cephalic prolonga- tion of the spinal cord generally known as the medulla oblongata, ap- proaches very closely in some animals to the regular type of the spinal nerves; and though in Man it still manifests an irregularity, in having only a single root, yet this irregularity is often shared by the first cervical

* 'Recherches Expérimentales sur les Fonctions du Nerf Spinal,' in "Archives de Médecine," 1844. This Memoir, having gained the prize given by the Académie des Sciences for experimental physiology in 1845, has been printed in the "Recueil des Savants étrangers," tom. xi., 1851 ; and the author states that since the first publication of his researches, he has confirmed his original conclusions by the repetition and variation of his experiments.

nerve, which also has sometimes an anterior root only.—The Hypoglossal nerve is distributed not merely to the tongue, but to the muscles of the neck which are concerned in the movements of the larynx; and the purpose of this distribution is probably to associate them in those actions, which are necessary for articulate speech. Though *all* the motions of the tongue are performed through the medium of this nerve, yet it would appear, from pathological phenomena, to have at least two distinct connections with the nervous centres; for in many cases of paralysis, the masticatory movements of the tongue are but little affected, when the power of articulation is much injured or totally destroyed; and the converse may be occasionally noticed. When this nerve is paralyzed on one side, in hemiplegia, it will be generally observed that the tongue, when the patient is directed to put it out, is projected *towards* the palsied side of the face: this is due to the want of action of the lingual muscles of that side, which do not aid in pushing forward the tip; the point is consequently directed only by the muscles of the other side, which will not act in a straight direction, when unantagonized by their fellows. It is a curious fact, however, that the Hypoglossal nerve seems not to be always palsied on the same side with the Facial, but sometimes on the other. This has been suggested to be due to the origination of the roots of this nerve from near the point at which the pyramids of the medulla oblongata decussate, so that some of its fibres come off, like those of the spinal nerves, without crossing, whilst others are transmitted to the opposite side, like those of the higher cephalic nerves; and the cause of paralysis may affect one or other of these sets of roots more particularly. Whatever may be the validity of this explanation, the circumstance is an interesting one and well worthy of attention.*

721. The *general character* and *arrangement* of the Cephalic nerves, as distinguished from the ordinary Spinal, constitute a study of much interest, when considered in relation to Comparative Anatomy, and to Embryology. It appears, from what has been already stated, that the Pneumogastric, Spinal Accessory, Glosso-pharyngeal, and Hypoglossal nerves, may be considered nearly in the light of ordinary Spinal nerves. They all take their origin exclusively in the Medulla Oblongata; and the want of correspondence in position, between their roots and those of the Spinal nerves, is readily accounted for, by the alteration in the direction of the columns of the Spinal cord, which not only decussate laterally, but, as it were, antero-posteriorly (§ 711). The Hypoglossal, as just stated, not unfrequently possesses a sensory in addition to its motor root. The Glosso-pharyngeal, which is principally an afferent nerve, has a small motor root; but most of the motor fibres which answer to it are to be found in the Pneumogastric. That the Pneumogastric and Spinal Accessory together represent a Spinal nerve, may be regarded as probable from what has been already said of their relations.

722. Leaving these nerves out of the question, therefore, we proceed to

* It may be questioned, however, whether the Hypoglossal is really paralyzed on the opposite side from the Facial in such cases. An instance has been communicated to the Author by Dr. W. Budd, in which the hypoglossal nerve was completely divided on one side; and yet the tip of the tongue, when the patient was desired to put it out, was sometimes directed *from* and sometimes *towards* the palsied side; showing that the muscles of either half are sufficient to give any required direction to the whole.

e rest. Comparative anatomy, and the study of Embryonic development, ke show that the Spinal Cord and Medulla Oblongata constitute the most sential part of the nervous system in Vertebrata; and that the Cerebral emispheres are superadded, as it were, to this. At an early period of elopment, the Encephalon consists chiefly of four vesicles, which correspond with the ganglionic enlargements of the nervous cord of the rticulata, and mark four divisions of the Cerebro-Spinal axis; and, in cordance with this view, the Osteologist is able to trace, in the bones of e cranium, the same elements which would form four vertebræ, in a uch expanded and altered condition.* However improbable such an ea might seem, when the cranium of the higher Vertebrata alone is amined, it at once reconciles itself to our reason, when we direct our tention to that of Reptiles and Fishes; in which classes the size of the erebral or hemispheric ganglia is very small, in comparison with that of e ganglia of Special Sensation; and in which the latter evidently form it a continuation of the Spinal Cord, modified in its function: so that, hen we trace upwards the cavity of the spinal column into that of the anium, we encounter no material change, either in its size or direction. he four pairs of nerves of special sensation,—Auditory, Gustatory, Optic, nd Olfactory,—make their way out *through* these three cranial vertebræ espectively. At a later period of development, other nerves are interposed *tween* these; which, being *intervertebral*, are evidently more analogous the Spinal nerves, both in situation and function. A separation of the rimitive fibres of these takes place, however, during the progress of development, so that their distribution appears irregular. Thus the greater art of the sensory fibres are contained in the large division of the Trigeminus: whilst of the motor fibres, the anterior ones chiefly pass forwards s the Oculo-motor and Patheticus; and of the posterior, some form the mall division of the Trigeminus, and others unite with the first pair from he Medulla Oblongata to form the Facial. This last fact explains the lose union, which is found in Fishes and some Amphibia, between that erve and those proceeding more directly from the Medulla Oblongata. According to Valentin, the Glosso-pharyngeal is the sensory portion of the irst pair from the Medulla Oblongata, of which the motor part is chiefly omprehended in the Facial nerve. Although we are accustomed to onsider the Fifth pair as *par éminence* the Spinal nerve, of the head, the oregoing statements, founded upon the history of development,† show hat the nerves of the Orbit really belong to its motor portion; they may onsequently be regarded as altogether forming the *first* of the *intervertebral* nerves of the cranium. The Facial and Glosso-pharyngeal appear to onstitute the *second;* whilst the Par Vagum and Spinal Accessory, forming the *third* pair, intervene between this and the true Spinal, of which the Hypoglossal may be considered as the first.

723. *Functions of the Spinal Axis.*—Whatever view we may take of the structure of the Spinal Cord, no doubt can be fairly entertained that it must be physiologically treated on the one hand as a true centre (or rather as an aggregation of separate centres) of nervous power, and on

* See "Princ. of Phys., Gen. and Comp.," § 320 *i*; and Prof. Owen's "Archetype Skeleton."

† See Prof. Valentin "De Functionibus Nervorum Cerebralium et Nervi Sympathici," Bernæ, 1839; lib. iii. cap. i.

the other as a medium of conduction between the Encephalic centres and the roots of the Spinal nerves. And although its attributes as an independent centre become most obvious when it is separated from the rest, yet there can be no reasonable doubt that it is always acting as such, even when every part of the Nervous System is in a state of complete vigour. It may, in fact, be said to supply, by its 'reflex power,' *the conditions requisite for the maintenance of the various Organic processes;* and, as Dr. M. Hall has pointed out, it especially governs the various orifices of ingress and egress. Thus the act of Deglutition is entirely dependent upon the Spinal Axis and the nerves proceeding from it; the Will being in no other way concerned in it, than by originating the necessary stimulus; and even sensation not being a necessary link in the chain of excito-motor action (§§ 426—428). The action of the cardiac sphincter, again,—and probably that of the pyloric sphincter also,—is dependent upon its nervous connection with the Spinal Axis; and is entirely regulated without sensorial excitement (§ 428). And there is much reason to believe that certain of the movements of the Stomach itself are in like manner dependent upon its connection with the Medulla Oblongata (§ 430); although it unquestionably possesses an independent motor activity of its own. The movements of the Intestinal tube are undoubtedly influenced by the Spinal Cord, although essentially independent of it (§§ 432, 433); but the sphincter which surrounds its orifice of egress is undoubtedly placed under its guardianship, although partly subjected (in Man) to the control of the Will. The same may be said of the *expulsor* muscles concerned in the act of Defecation; and of the expulsors and sphincter which effect and control the act of Urination (§ 434).—Looking, again, at the movements which are subservient to the Respiratory process, we find that all those which are essential to its regular maintenance are performed through the intermediation of the Spinal Axis alone; that the Will has only such a limited power over them, as to bring them into harmony with its other requirements, as in the acts of vocalization and in extraordinary muscular exertions; and that the stimulus by which they are commonly maintained does not even affect the consciousness, the 'besoin de respirer' only becoming *sensible* when the respiratory process is being imperfectly performed (§§ 548—551). Not only are the ordinary respiratory movements performed through this channel, but the aperture of the Glottis is regulated by it, in everything that concerns the respiration; and either by its spasmodic closure against the entrance of unfit substances, or by the expulsor effort of coughing, which is excited by them when they do find their way into the air-passages, these passages are kept free from solid, liquid, or gaseous particles, whose presence in them would be injurious.—In the expulsion of the Generative products, also, the reflex power of the Spinal Cord takes an important share. The muscular contractions which produce the Emissio Seminis are excito-motor in their nature; being independent of the Will, and not capable of restraint by it when once fully excited; and being (like those of Deglutition) excitable in no other way, than by a particular local irritation. It has been shown by experiment, and also by pathological observation, that the separation of the lower portion of the Spinal Cord from the upper does not prevent these movements from being excited, although the act is then unaccompanied with sensation,

hich proves that sensation is not essential to its performance; on .e other hand, the power of emission is annihilated by destruction of ie lower portion of the Spinal Cord, or by section of the nerves which .pply the genital organs. The act of Parturition, however, seems to be ss dependent upon the Spinal Cord; for, as will be shown hereafter HAP. XIX.), the contractions of the Uterus, which are alone sufficient to xpel the fœtus when there is no considerable resistance, are not to be egarded as reflex; and it is only in the co-operation of those associated iuscles which come into play in the second stage of labour, when the ead is passing through the os uteri and is engaged in the pelvic cavity, iat the assistance of the Spinal cord and its nerves is called-in. These aovements, like those of Defecation, may be to a certain extent promoted r restrained by voluntary effort; but when the exciting influence (the ressure of the head against the parietes of the vaginal canal) has once een fully brought into operation by the uterine contractions, the Will has ittle power over them, either in one way or the other. The antagonizing nfluence of the sphincter vaginæ seems, like that of the sphincter ani, o be dependent upon the Spinal Cord; and thus it happens that when ts tension and that of other muscular parts has been destroyed by leath, whilst the uterus still retains its contractility, the power of the atter has sufficed for the completion of the parturient process, the child being expelled after the respiratory movements have ceased.

724. The Spinal Cord is not merely the instrument whereby the movenents essential to the maintenance of the Organic functions are susained; it is also subservient to other muscular actions whose character is essentially *protective.* Thus it was ascertained by Dr. M. Hall * that, f the functions of the Brain be suspended or destroyed, without injury o the Spinal Cord and its nerves, the Orbicularis muscle will contract, so as to occasion the closure of the eyelids, upon their tarsal margin being ouched with a feather. This fact is interesting in several points of view. In the first place, it is a characteristic example of pure reflex action, occurring under circumstances in which volition cannot be imagined to guide it, and in which there is no valid reason to believe that sensation directs it. Further, it explains the almost irresistible nature of the tendency to winking, which is performed at short intervals by the contraction of the Orbicularis muscle; this is evidently a Spinal action, capable of being in some degree restrained (like that of respiration) by the will, but only until such time as the stimulus (resulting perhaps from the collection of minute particles of dust upon the eyes, or from the dryness of their surface in consequence of evaporation,) becomes too strong to be any longer resisted. Again, we have in sleep or in apoplexy an example of this purely spinal action, unbalanced by the influence of the will, which, in the waking state, antagonizes it by calling the levator palpebræ into action. As soon as the will ceases to act, the lids droop, and close over the eye in order to protect it; and if those of a sleeping person be separated by the hand, they will be found presently to return. Here, as in studying the respiratory and other movements, we are led to perceive that it is the Brain alone which is torpid during sleep, and whose functions are affected by this torpidity. As Dr. M. Hall

* "Memoirs on the Nervous System," 1837, p. 61.

very justly remarks, "the Spinal system never sleeps;" it is constantly in activity; and it is thus that, in all periods and phases of Life, the movements which are essential to its continued maintenance are kept up without sensible effort.—The closure of the pupil against a strong light, is another movement of the same protective tendency. The channel through which that just named is performed, is completed by the first branch of the Fifth and the Portio Dura of the seventh. The contraction of the pupil is immediately caused by the Third pair, or Motor Oculi, as is easily shown by irritating the trunk of that nerve and observing the result; but the stimulus which excites it is conveyed through the Optic nerve. But although the contraction of the pupil is usually in close accordance with the *sensation* occasioned by the impression of light upon the retina, yet there is evidence to prove that the sensation of light is not always necessary; for, even when the sight of both eyes has been entirely destroyed by amaurosis, the regular actions have been witnessed in the pupil, in accordance with varying degrees of light impinging on the retina. Such cases seem to indicate that the motion results from an *impression* upon the retina, which impression, being conducted to the Sensorium, ordinarily produces a sensation; but that even where no sensation is produced, on account of a disordered state of the part of the ganglionic centre in which the Optic nerve terminates, if the central tract which connects that nerve with the Third pair retain its integrity, a reflex action may be excited through it, although no sensation intervene. The rarity of the occurrence is easily accounted for, by the fact that in most cases of amaurosis, the disease lies in the retina or in the trunk of the nerve, and thereby checks both its spinal and its encephalic actions. —Although we are not at present acquainted with any similar protective movements, in the Human being, designed to keep the organ of Hearing from injury; yet there can be little doubt that those which we are constantly witnessing in other animals, possessing large external ears, are reflex actions excited by the irritation applied to them. In regard to the Nose, we find a remarkably complex action—that of Sneezing—adapted to drive off any cause of irritation (§ 555). The stimulus is conveyed, in this case, not through the Olfactory nerve, but through the Fifth pair; so that it is not dependent upon the excitement of the sensation of Smell. The act of Coughing, also, may be regarded as of a protective character; being destined to remove sources of irritation from the air-passages. Many of the automatic movements, performed by the limbs of Frogs and other animals, when their connection with the brain has been cut off, appear destined to remove these parts from sources of irritation or injury; and they may thus be rightly placed under the same category.

725. The fact that Sensation is very commonly *associated with* the reflex actions we have been considering, being produced by the impression that excites them, has led many to suppose that it necessarily participates in them;—a doctrine which we have seen to be untenable. But the question not unnaturally arises, *why* Sensation should so constantly participate in these operations, if not essential to them; and the answer to this question is to be found in the fact, that it is only through sensation that a higher set of actions, mental and bodily, is called into play, which is essential to the *continued maintenance* of those belonging to the present category. Illustrations of this truth might be drawn from any

one of the functions already noticed; but the Ingestion of food will supply us with one of the most apposite. We have seen that the act of Deglutition is in itself independent of sensation; anything that comes within the grasp of the pharyngeal constrictors being conveyed downwards by their reflex contraction, just as anything which touches the arms of a Polype is entrapped by them and drawn into the stomach. Now this action may be considered as attended with sensation, in the ordinary condition of the higher Animal, in order that it may be guided in the performance of those other movements of prehension, mastication, &c., by which the food may be brought within reach of the apparatus of deglutition; and the sensations which are linked with these are among the influences which prompt to those mental operations, whereby food is provided for the digestive apparatus to make use of. The Zoophyte is dependent for its supplies of aliment, upon what the currents in the surrounding fluid, or other chances, may bring into its neighbourhood; and if these should fail, it starves. The anencephalous Infant, again, can swallow, and even suck; but it can execute no other movements adapted to obtain the supply of food continually necessary for maintenance, because it has not a mind which sensations could awake into activity. The sensation connected with excito-motor actions has not only this important end, but it frequently contributes to enjoyment, as in Suction and Ejaculatio seminis. The sensation accompanying the actions of this class, moreover, frequently affords premonition of danger, or gives excitement to supplementary actions destined to remove it, as in the case of Respiration; for where anything interferes with the due discharge of the function, the uneasy sensation that ensues occasions unwonted movements, which are more or less adapted to remove the impediment, in proportion as they are guided by judgment as well as by consciousness. Again, sensation often gives warning against inconvenience, as in the Excretory functions; and here it is very evident, that its purpose is not only (if it be at all) to excite the associated muscles necessary for the excretion, but actually to make the will set up the antagonizing action of the sphincters (§ 434).

726. We have now to inquire how far the independent action of the Spinal Cord is concerned in the general muscular movements of Man, and especially in the locomotive actions of his lower extremities. On this point it is obvious that we must not be guided by the analogy of the lower animals; since in Man the locomotive and other movements are for the most part volitional and purposive, and he has to acquire by experience that control over his muscular apparatus which is necessary to enable him to perform them; whilst in Invertebrata generally, and in a large part of the lower Vertebrata, it is evident that the movements of progression, &c. which are characteristic of each species, come under the general category of automatic actions, and are provided-for in the original organization of its nervous centres, being performed without any education, and under circumstances which render the notion of a purpose on the Animal's own part quite untenable. In so far as these instinctive movements require the guidance and direction of sensations, they must be referred to the 'consensual' group; but clear evidence is afforded by the continuance of many of them after the removal of the centres of sensation, that they are excito-motor in their character, and that they require

no higher centre than the ganglia which correspond to the Spinal Cord of Man.* There can be little doubt that the habitual movements of locomotion, and others which have become 'secondarily automatic,' may be performed by Man under particular circumstances through the agency of the Spinal Cord alone, under the guidance and direction of the Sensorial centres, or even without such guidance; the required condition being, that the influence of the Cerebrum shall be entirely withdrawn. There are numerous instances on record, in which soldiers have continued to *march* in a sound sleep; and the Author has been assured by an intelligent witness, that he has seen a very accomplished pianist complete the performance of a piece of music in the same state.† A case has been mentioned to him by his friend Dr. William Budd, of a patient who laboured under that form of epilepsy in which there was simply a temporary suspension of consciousness without convulsion; and whenever the paroxysm came on, he persisted in the kind of movement in which he was engaged at the moment, having on one occasion fallen into the water through continuing to walk onwards, and having on several occasions (being a shoemaker by trade) wounded his fingers with the awl in his hand, by a repetition of the movement by which he was endeavouring to pierce the leather. Such facts as these add great strength to the probability, that when the Cerebral power is not suspended, but merely directed into another channel, as in the states of reverie or abstraction, and the attention is entirely drawn-off from the movements of locomotion, the continuance of these is due to the independent automatic action of the Spinal Cord, the direction being given to them by the Sensory Ganglia. This point, however, will be more fully considered hereafter (§ 749); at present it may be remarked, that, when a regular train of movements is being performed under such conditions, each action may be probably regarded as affording the stimulus to the next; each contact of the foot with the ground, in the act of walking, exciting the muscular contractions which constitute the next step;‡ and each movement of the musician exciting that which has customarily followed it, after the same fashion.— Now in all these cases, it seems reasonable to infer, that the same kind of connection between the excitor and motor nerves comes to be formed by a process of gradual development, as originally exists in the nervous systems of those animals whose movements are entirely automatic. Whether there is in any case an actual continuity of nerve-fibres, may be reasonably doubted. That such a peculiar continuity is not requisite, in order to allow an excitor impression made upon one part of the Cord, to call forth motions through another, may be certainly inferred from the fact, that under particular circumstances we find the influence of such impressions radiating in every direction, and extending to nerves which they do not ordinarily affect (§ 728). Still there can be no doubt that the nerve-

* See "Princ. of Phys., Gen. and Comp.," §§ 769–771.

† In playing by memory on a musical instrument, the *muscular* sense often suggests the sequence of movements with more certainty than the *auditory;* and since the impressions derived from the muscles may prompt and regulate successional movements without affecting the consciousness, there is no such improbability in the above statement as might at first sight appear.

‡ The truth of this view seems to the Author to be strongly supported by observation of the mode in which Infants learn to walk; for long before they can stand, they will instinctively perform the movements of walking, if they be so supported that the feet touch the ground.

force is disposed to pass in special *tracks;* and it seems probable that whilst some are originally marked-out for the automatic movements, others may be gradually worn-in (so to speak) by the habitual action of the Will; and that thus, when a train of sequential actions originally directed by the Will has been once set in operation, it may continue without any further influence from that source.

727. Another manifestation of the independent power of the Spinal Cord, is seen in its influence on *Muscular Tension.*—The various muscles of the body, even when there is the most complete absence of effort, maintain, in the healthy state of the system, a certain degree of firmness, by their antagonism with each other; and if any set of muscles be completely paralyzed, the opposing muscles will draw the part on which they act out of its position of repose; as is well seen in the distortion of the face which is characteristic of paralysis of the facial nerve on one side. This condition has been designated as the *tone* of the Muscles; but this term renders it liable to be confounded with their *tonic contraction* (§ 331), which is also concerned in maintaining their firmness, but which is a manifestation of the simple contractility of their tissue, and is exhibited alike by the striated and the non-striated forms of muscular fibre, but more especially by the latter. On the other hand, the condition now alluded to, which may perhaps be appropriately termed their *tension,* is the result of a moderate though continued excitement of that contractility, through the nervous centres. It has been proved by Dr. M. Hall, that the Muscular Tension is not dependent upon the influence of the Brain, but upon that of the Spinal Cord; as the following experiments demonstrate.—"Two Rabbits were taken; from one the head was removed; from the other also the head was removed, and the spinal marrow was cautiously destroyed with a sharp instrument:—the limbs of the former retained a certain degree of firmness and elasticity; those of the second were perfectly lax." Again: "The limbs and tail of a decapitated Turtle possessed a certain degree of firmness or tone, recoiled on being drawn from their position, and moved with energy on the application of a stimulus. On withdrawing the spinal marrow gently out of its canal, all these phenomena ceased. The limbs were no longer obedient to stimuli, and became perfectly flaccid, having lost all their resilience. The sphincter lost its circular form and contracted state, becoming lax, flaccid, and shapeless. The tail was flaccid, and unmoved on the application of stimuli." * It is further remarked by Messrs. Todd and Bowman, that "a decapitated frog will continue in the sitting posture through the influence of the spinal cord; but immediately this organ is removed, the limbs fall apart."—This operation of the Spinal Cord is doubtless but a peculiar manifestation of its ordinary reflex function. We shall hereafter see (§ 750) how much the influence of the Will in producing the active contraction of a muscle, is connected with sensations received from it; and it seems highly probable, that the impression of the state of the muscle, conveyed by the afferent fibres proceeding from it to the spinal cord, is sufficient to excite this state of moderate tension through the motor nerves arising from the latter. Such a view derives probability from the fact, which must have fallen under the observation of almost

* "Memoirs on the Nervous System," 1837, p. 93.

every one, that most reflex actions become increased in energy if resistance be made to them. Of this we have familiar examples in the action of the expulsor muscles, which operate in defecation, urination, and parturition, if, when they are strongly excited, their efforts be opposed by spasmodic contraction of the sphincters, or by mechanical means. Many forms of convulsive movement exhibit the same tendency, their violence being proportional to the mechanical force used to restrain them.* Here it is evident that the *impression of resistance*, conveyed to the Spinal Cord, is the source of the increased energy of its motor influence; from which we may fairly infer that the moderate resistance, occasioned by the natural antagonism of the muscles, is the source of their continued and moderate tension, whilst they are under the influence of the Spinal Cord. This constant though gentle action serves to keep up the nutrition of the muscles, which are paralyzed to the will; and this is still more completely maintained, if the portion of the nervous centres, with which they remain connected, be so unduly irritable, that the muscles are called into contraction upon the slightest excitation, and are thus continually exhibiting twitchings, startings, or more powerful convulsive movements. It is upon the state of nutrition of the muscles, that their contractility depends (§ 313); and hence the Spinal Cord has an indirect influence upon this peculiar property, which is more likely to be retained, when the muscle is still subject to the influence of the Spinal Cord, though cut off from that of the Brain, than when it is completely paralyzed by the entire separation of its connection with the nervous centres.

728. The functional activity of the Spinal Cord is capable of being morbidly diminished or augmented. It may even be for a time almost completely suspended, as in Syncope; which state may be induced by sudden and violent impressions, either of a mental or physical nature, that operate upon the whole nervous system at once—commencing, however, in the Brain. It is to be remarked that, in recovering from these, it is the Spinal system of which the activity is first renewed; the respiratory movements recommencing, and the power of swallowing being restored, before any voluntary actions can be performed. A corresponding state may be induced in particular portions of the system, by Concussion; as is seen in severe injuries of the Spinal Cord, which are almost invariably followed for a time by the suspension of its functions. Again, the power of the whole Spinal Cord may be diminished by various causes, such as enfeebled circulation, pressure, &c.; and then we have torpidity and imperfect nutrition of the whole muscular system.† If oppression

* Hence the absurdity of the common practice of endeavouring to *prevent* the movements of the limbs and body, in convulsive paroxysms, by mechanical constraint. Nothing should be attempted but what is requisite to prevent the sufferer from doing himself an injury.

† A case has been for some time under the Author's observation, in which the males of a family have been successively affected with a general muscular debility, commencing in the lower extremities, which is pretty obviously traceable to deficient functional activity of the Spinal Cord. The affection has manifested itself during the earlier years of childhood; and in the two elder sons has advanced until it has produced an almost complete general paralysis, with fatty degeneration of the muscles. In a younger son, in whom the same affection had distinctly begun to manifest itself, it has been kept in check by very careful attention to every means that can favour healthy nutrition and development of nervous power; among which, constant exercise, and the frequent transmission of feeble electrical currents down the spine and from the spine to the limbs, have seemed the most effectual.

exist in the Brain, the functions of the Medulla Oblongata will be especially affected; and if it be prolonged and sufficiently severe, Asphyxia will result from the interruption of the respiratory movements which it occasions. — On the other hand, the excitability of the whole Cord, or of particular parts of it, may be morbidly increased.* This is especially seen in ordinary Tetanus, and in the artificial Tetanus induced by Strychnine; in which the slightest external stimulus is sufficient to induce reflex actions in their most terrific forms. It is interesting to remark, that in this formidable disease, the functions of the muscles controlling the various orifices are those most affected; and it is by the spasms affecting the organs of respiration or deglutition, that life is commonly terminated. In some forms of Hysteria, also, there is a morbid excitability of the same kind, so that various kinds of convulsions are brought on by very slight stimuli; and Infantile convulsions are generally attributable to the same kind of disorder of the nervous centres, which is frequently induced by bad air, unwholesome food, or some other cause that affects the purity of the blood (§ 583). Not only is the general muscular system of Animal life involved in these abnormal actions, but various parts of the apparatus of Organic life have their normal functions seriously perverted by the same condition of the Spinal Cord; being connected with it through the medium of the Sympathetic system of nerves, whose motor powers are chiefly, if not entirely, derived from that source (Sect. 6).—Various remedial agents will probably be found to operate, by occasioning increased excitability in some particular segments of the Cord; so that the usual stimuli applied to the parts connected with these, will occasion increased muscular tension. This seems to be the case, for example, in regard to the influence of aloes on the rectum and uterus, cantharides on the neck of the bladder and adjoining parts, and secale cornutum on the uterus. The mode of influence of cantharides is illustrated by a curious case, related by Dr. M. Hall, of a young lady who lost the power of retention of urine, in consequence of a fatty tumour in the spinal canal, which gradually severed the Spinal Cord, and induced

* It has been pointed out by Messrs. Todd and Bowman ("Physiological Anatomy," vol. i. p. 315), that the Spinal Cord of the male frog, at the season of copulation, naturally possesses a state of most extraordinary excitability. The thumb of each anterior extremity at this season, becomes considerably enlarged; as is well known to Naturalists. "This enlargement is caused principally by a considerable development of the papillary structure of the skin which covers it; so that large papillæ are formed all over it. A male frog, at this season, has an irresistible propensity to cling to any object, by seizing it between his anterior extremities. It is in this way that he seizes upon, and clings to the female; fixing his thumbs to each side of her abdomen, and remaining there for weeks, until the ova have been completely expelled. An effort of the Will alone could not keep up the grasp uninterruptedly for so long a time; yet so firm is the hold, that it can with difficulty be relaxed. Whatever is brought in the way of the thumbs, will be caught by the forcible contraction of the anterior limbs; and hence we often find frogs clinging blindly to a piece of wood, or a dead fish, or some other substance which they may chance to meet with. If the finger be placed between the anterior extremities, they will grasp it firmly; nor will they relax their grasp until they are separated by force. If the animal be decapitated, whilst the finger is within the grasp of its anterior extremities, they still continue to hold on firmly. The posterior half of the body may be cut away, and yet the anterior extremities will still cling to the finger; but immediately that the segment of the cord, from which the anterior extremities derive their nerves, has been removed, all their motion ceases. This curious instinct only exists during the period of sexual excitement; for at other periods the excitability of the anterior extremities is considerably less than that of the posterior."

paraplegia. The power of retaining the urine was always restored *for a time* by a dose of tincture of cantharides, which seems to have acted by augmenting the excitability of that segment of the Cord, with which the sphincter vesicæ is connected.

### 3.—*Of the Sensory Ganglia and their Functions.—Consensual Movements.*

729. At the base of the Brain in Man, concealed by the Cerebral Hemispheres, but still readily distinguishable from them, we find a series of ganglionic masses; which are in direct connection with the nerves of Sensation; and which appear to have functions quite independent of those of the other components of the Encephalon.—Thus anteriorly we have the *Olfactive* ganglia, in what are commonly termed the bulbous expansions of the Olfactive nerve. That these are real ganglia, is proved by their containing grey or vesicular substance; and their separation from the general mass of the Encephalon, by the peduncles or footstalks commonly termed the trunks of the Olfactory nerves, finds its analogy in many species of Fish. The ganglionic nature of these masses is more evident in many of the lower Mammalia, in which the organ of Smell is highly developed, than it is in Man, whose olfactive powers are comparatively moderate.—At some distance behind these, we have the representatives of the *Optic* ganglia, in the Tubercula Quadrigemina, to which the principal part of the roots of the Optic nerve may be traced. Although these bodies are so small in Man, in comparison with the whole Encephalic mass, as to be apparently insignificant, yet they are much larger, and form a more evidently important part of it in many of the lower Mammalia; though still presenting the same general aspect.—The *Auditory* ganglia do not form distinct lobes or projections; but are lodged in the substance of the Medulla Oblongata. Their real character is most evident in certain Fishes, as the Carp; in which we trace the Auditory nerve into a ganglionic centre as distinct as the Optic ganglion. In higher animals, however, and in Man, we are able to trace the Auditory nerve into a small mass of vesicular matter, which lies on each side of the Fourth Ventricle; and although this is lodged in the midst of parts whose function is altogether different, yet there seems no reason for doubting that it has a character of its own, and that it is really the ganglionic centre of the Auditory nerve.—In like manner, we may probably fix upon a collection of vesicular matter, imbedded in the Medulla Oblongata,—which is considered by Stilling to be the nucleus of the Glosso-pharyngeal nerve, and to which a portion of the sensory root of the Fifth pair may be also traced,—as representing the *Gustatory* ganglion.

730. At the base of the Cerebral Hemispheres, we find two other large ganglionic masses, on either side; through which nearly all the fibres appear to pass, that connect the Hemispheres with the Medulla Oblongata. These are the *Thalami Optici*, and the *Corpora Striata*. Now, although these are commonly regarded in the light of appendages, merely, to the Cerebral Hemispheres, it is evident, from the large quantity of vesicular matter they contain, that they must rank as independent ganglionic centres; and this view is supported alike by the evidence of Comparative Anatomy, and by that afforded by the history of Development. For it is certain that the size of the Thalami Optici and Corpora Striata

presents no more relation, in different tribes of animals, to that of the Cerebrum, than does that of the ganglia of Special Sense; and they may even present a considerable development, when the condition of the Cerebrum is quite rudimentary. Thus in the Osseous Fishes, a careful examination of the relations of the body which is known as the Optic lobe (Fig. 128, C) makes it apparent that this is not merely the representative of the proper Optic Ganglion of Man, but also of the Thalamus Opticus; whilst, again, the mass which is designated as the Cerebral lobe (B) is chiefly homologous with the Corpus Striatum of higher animals. The nature of the latter body is made apparent, in the higher Cartilaginous Fishes, by the presence of a ventricle in its interior; the floor of this cavity being formed by the Corpus Striatum, whilst the thin layer of nervous matter which forms its roof is the only representative of the Cerebral hemisphere. So in the Human embryo of the 6th week, we find a distinct vesicle for the Thalami Optici, interposed between the vesicle of the Corpora Quadrigemina and that which gives origin to the Cerebral Hemispheres; whilst the Corpora Striata constitute the floor of the cavity or ventricle which exists in the latter, this being as yet of comparatively small dimensions.—Now, as already pointed out, we may distinguish in the Medulla Oblongata and Crura Cerebri, a *sensory* and *motor* tract; by the endowments of the nerves which issue from them. The sensory tract may be traced upwards, until it almost entirely spreads itself through the substance of the Thalamus. Moreover, the Optic nerves, and the peduncles of the Olfactive, may be shown to have a distinct connection with the Thalami; the former by the direct passage of a portion of their roots into these ganglia; and the latter through the medium of the Fornix. Hence we may fairly regard the *Thalami Optici* as the chief focus of the *Sensory* nerves, and more especially as the ganglionic centre of the nerves of *common* sensation, which ascend to it from the Medulla Oblongata and Spinal Cord.—On the other hand, the *Corpora Striata* are implanted on the *Motor* tract of the Crura Cerebri, which descend into the Pyramidal columns; and their relation to the fibres of which that tract is composed, appears to be essentially the same as that which the Thalami bear to the sensory tract. Upon the precise nature of that relation, Anatomists are not agreed; but there are several considerations which render it propable that there is *not* that continuity between the fibres of the Crura Cerebri, and those which radiate from the Thalami Optici and Corpora Striata to the surface of the Hemispheres, which a superficial examination would seem to indicate; but that the fibres which ascend from the Crura Cerebri for the most part, if not entirely, terminate in the vesicular substance of the former bodies, and that the radiating fibres of the latter take a fresh departure from them.* At any rate, as we shall see hereafter, there is a complete *physiological* separation between the Cerebrum and the Sensory Ganglia upon which it is superposed.

731. The Thalami Optici, and the Corpora Striata, as is well-known, are very closely connected with each other by commissural fibres; and, if the preceding account of their respective offices be correct, they may be regarded as having much the same relation to each other, as that which exists between the posterior and anterior peaks of vesicular matter in the

* See especially Messrs. Todd and Bowman's "Physiological Anatomy," vol. i. p. 277, and Prof. Kölliker's "Mikrokopische Anatomie," band ii. § 118.

Spinal Cord;* the latter issuing motor impulses in respondence to sensations excited through the former. They are also closely connected with other ganglionic masses in their neighbourhood, such as the Locus Niger, and the vesicular matter of the Tuber Annulare; which, again, are in close relation with the vesicular matter of the Medulla Oblongata.—Altogether it is very evident, that a series of true ganglionic centres exists at the base of the Encephalon, and that these are really as distinct from either the Cerebrum or Cerebellum, as the latter are from each other; and we have next to inquire, what functions are to be assigned to them.

732. The determination of these may seem to be the more difficult, as it is impossible to make any satisfactory experiments upon the ganglionic centres in question, by isolating them completely from the Cerebral Hemispheres above, and from the Medulla Oblongata and Spinal Cord below. But the evidence derived from Comparative Anatomy appears to be in this case particularly clear; and, rightly considered, affords us nearly all the information we require. In the series of "experiments prepared for us by nature," which is presented to us in the descending scale of Animal life, we witness the effects of the gradual change in the relative development of the Sensory ganglia and Cerebral Hemispheres, which are presented to us in the Vertebrated classes; and the results of the entire withdrawal of the latter, and of the sole operation of the former, which are presented in the higher Invertebrata. For the Sensory ganglia gradually increase, whilst the Cerebral hemispheres as regularly diminish, in relative size and importance, as we descend from the higher Mammalia to the lower,—from these to Birds,—thence to Reptiles,—from these, again, to the higher Fishes, in which the aggregate size of the Sensory ganglia equals that of the Cerebrum,—thence to the lower Fishes, in which the size of the Cerebral lobes is no greater than that of a single pair of sensory ganglia, the Optic, and frequently even inferior,—and lastly, to the *Amphioxus* or Lancelot, the lowest Vertebrated animal of which we have any knowledge, in which there is not the rudiment of a Cerebrum, the Encephalon being only represented by a single ganglionic mass, which, from its connection with the nerves of sense, must obviously be regarded as analogous to the congeries of ganglia that we find in the higher forms of the class.—Descending to the Invertebrated series, we find that, except in a few of those which border most closely upon Vertebrata (such, for example, as the Cuttle-Fish), *the whole* Cephalic mass appears to be made up of ganglia in immediate connection with the Nerves of Sense. These may appear to form but a single pair; yet they are in reality composed of *several pairs*, fused (as it were) into one mass. Of this we may judge by determining the number of distinct pairs of nerves which issue from them; and also by the investigation of the history of their development, the results of which bear a close correspondence with those obtained in the preceding method.—It is further to be remarked, that the development of the Cephalic ganglia in the Invertebrata always bears an exact proportion to the development of the *eyes;* the other organs of special sense being comparatively undeveloped; whilst these, in all the higher classes at least, are instruments of great perfection, and are evidently connected most intimately with the direction of the movements

* This was first pointed out by Messrs. Todd and Bowman in their "Physiological Anatomy," vol. i. pp. 347-350.

the animals. Of this fact we have a remarkable illustration in the story of the metamorphosis of Insects; the eyes being almost rudiment- y, and the Cephalic ganglia comparatively small, in most Larvæ; whilst th these organs attain a high development in the Imago, to whose tions the faculty of sight is essential.*

733. Thus we are led by the very cogent evidence which Comparative natomy supplies, to regard this series of Ganglionic centres as constitut- g the real *Sensorium;* each ganglion having the power of communicating the mind the impressions derived from the organ with which it is con- ected, and of exciting automatic muscular movements in respondence to ese sensations. If this position be denied, we must either refuse the tribute of consciousness to such animals as possess no other encephalic ntres than these; or we must believe that the *addition* of the Cerebral emispheres, in the Vertebrated series, *alters* the endowments of the Sen- ry ganglia,—an idea which is contrary to all analogy.

734. So far as the results of Experiments can be relied on, they afford corroboration of this view. The degree in which animals high in the ale of organization can perform the functions of life, without any other entre of action than the Ganglia of Special sense, the Medulla Oblongata, nd the Cerebellum, appears extraordinary to those who are accustomed regard the Cerebral Hemispheres as the centre of all energy. From e experiments of Flourens,† Hertwig,‡ Magendie,§ Longet,|| and others, appears that not only Reptiles, but Birds and Mammals, may survive r many weeks or months (if their physical wants be duly supplied) fter the removal of the entire Cerebrum. It is difficult to substan- iate the existence in them of actual sensation; but some of their novements appear to be of a higher kind than those resulting from ere excito-motor action. One of the most remarkable phenomena xhibited by such a being, is the power of maintaining its equilibrium, which could scarcely exist without consciousness. If it be laid upon he back, it rises again; if pushed, it walks. If a Bird thus mutilated e thrown into the air, it flies; if a Frog be touched, it leaps. It wallows food and liquid, when they are placed in its mouth; and he digestive operations, the acts of excretion, &c., take place as usual. n the case of a Pigeon experimented on by Malacorps, which is recorded y Magendie, there appears sufficient proof of the persistence of a certain mount of sensation. Although the animal was not affected by a strong ight suddenly made to fall upon its eyes, it was accustomed, when con- ined in a darkened or partially-illuminated room, to seek out the light arts; and *it avoided objects that lay in its way.* In the same manner, it lid not seem to be affected by sudden noises; but at night, when it slept with closed eyes and its head under its wing, it would raise its head in a remarkable manner, and open its eyes, on the slightest noise; speedily relapsing into a state of complete unconsciousness. Its principal occupa- tion was to prune its feathers and scratch itself. And Longet mentions

* "See "Princ. of Phys., Gen. and Comp.," CHAP. XX. Sect. 2.

† "Recherches Expérimentales sur les propriétés et les functions du Système Nerveux," 2nd Edit. 1845.

‡ "Exper. de effect. læsion. in partibus Encephali," Berol., 1826.

§ "Leçons sur les Fonctions du Système Nerveux," Paris, 1839.

|| "Traité de Physiologie," tom. ii. partie 2.

that a Pigeon from which he had removed the entire Cerebrum, gave many indications of consciousness of light; not only the pupil contracting, but the lids closing, when a strong light was suddenly made to fall upon the eye, the animal having been previously kept in darkness; and *when a lighted candle was made to move in a circle before it, the animal executed a corresponding movement with its head.**—The condition of such beings seems to resemble that of a Man, who is in a slumber sufficiently deep to lose all distinct *perception* of external objects, but who is yet conscious of *sensations*, as appears from the movements occasioned by light or by sounds, or from those which he executes to withdraw the body from an uneasy position (§ 787).

735. The results of other Experiments made upon the Sensory ganglia themselves, and upon the organs from which they derive their impressions, confirm this view; by showing that the ordinary movements are seriously perturbed, and that in some instances a new set of automatic movements is induced, when the ordinary relations between the sensory and motor apparatus are disarranged. Among the ganglia of special sensation, the functions of the Optic Lobes, or *Corpora Quadrigemina*, have been chiefly examined experimentally. The researches of Flourens and Hertwig have shown, that their connection with the visual function, which might be inferred from their anatomical relations, is thus substantiated. The partial loss of the ganglion on one side produces partial loss of power and temporary blindness on the opposite side of the body, without necessarily destroying the mobility of the pupil; but the removal of a larger portion, or complete extirpation of it, occasions permanent blindness and immobility of the pupil, with temporary muscular weakness, on the opposite side. This temporary disorder of the muscular system sometimes manifests itself (as already stated) in a tendency to move on the axis, as if the animal were giddy. No disturbance of consciousness appears to be produced; and Hertwig states that he never witnessed the convulsions, which Flourens mentions as a consequence of the operation, and which were probably occasioned by his incision having been carried too deeply. As Longet has justly remarked, it is difficult, if not impossible, to remove one or both of these ganglionic masses, without doing such an injury to the Crura Cerebri on which they repose, as shall in great degree account for such disturbed movements (§ 738). Irritation of *one* of the Tubercula Quadrigemina has been observed, both by Flourens and Longet, to produce contraction of the pupils of *both* eyes.—These results of experiment are partly confirmed by Pathological phenomena in Man; for there are many instances on record, in which blindness has been one of the consequences of diseased alterations in one or both tubercles; and in some of the cases in which the lesion extended to parts seated beneath the tubercles, disturbed movements were observed.—The subservience of these bodies to the exercise of the visual sense, appears, on the whole, to be the point best established in regard to their functions; and considering the degree in which this sense is concerned in

* It must not be forgotten that, in such experiments, the severity of the operation will of itself occasion a suspension or disturbance of the functions of parts that remain; so that the *loss* of a power must not be at once inferred from the absence of its manifestations. But the *persistence* of a power, after the removal of a particular organ, is a clear proof that it cannot be the peculiar attribute of that organ.

› regulation of the general movements of the body, it is not surprising ιt lesions of its centre should occasion a perversion of these move- ·nts. This appears the more probable from the fact, that, in animals :ose Sensory ganglia bear so large a proportion to the whole Encephalon, ιt we must look upon them as the principal centres of motor activity, ;tead of being chiefly concerned (as in Man) in the mere guidance of ›vements whose origin is Cerebral, lesions of the organ of sense, from ιich the impressions that excite the sensori-motor impulses are derived, ›oduce a corresponding disturbance. Thus Flourens found that a ·rtiginous movement may be induced in Pigeons by simply blinding one e; and Longet produced the same effect by evacuating the humours of e eye.

736. It is probably on the same principle, that we are to account for e remarkable results obtained by Flourens (Op. cit.) from section of e portion of the Auditory nerve proceeding to the Semi-circular canals. ›ction of the horizontal semi-circular canal in Pigeons, on both sides, duces a rapid jerking horizontal movement of the head, from side to le; and a tendency to turn to one side, which manifests itself whenever e animal attempts to walk forwards. Section of a vertical canal, hether the superior or inferior, of both sides, is followed by a violent ›rtical movement of the head. And section of the horizontal and ›rtical canals, at the same time, causes horizontal and vertical move- ents. Section of either canal on one side only, is followed by the same fect as when the canal is divided on both sides; but this is inferior in tensity. The movements continue to be performed during several ιonths. In Rabbits, section of the horizontal canal is followed by the ιme movements as those exhibited by Pigeons; and they are even more ›nstant, though less violent. Section of the anterior vertical canal ιuses the animal to make continued forward 'somersets;' whilst section f the posterior vertical canal occasions continual backward 'somersets.' he movements cease when the animal is in repose; and they recom- ιence when it begins to move, increasing in violence as its motion is ιore rapid.—These curious results are supposed by M. Flourens to indi- ιte, that the nerve supplying the semi-circular canals does not minister › the sense of hearing, but to the direction of the movements of the nimal; but they are fully explained upon the supposition that the ormal function of the semi-circular canals is to indicate to the animal he *direction* of sounds, and that its movements are partly determined by hese; so that a destruction of one or other of them will produce an ·regularity of movement (resulting, as it would seem, from a sort of iddiness on the part of the animal), just as when one of the eyes of a ird is covered or destroyed, as in the experiments previously cited.

737. The numerous Experiments which have been made for the pur- ›ose of determining the functions of the Thalami Optici and Corpora triata, have not yielded any very satisfactory results; and this on account f the impossibility of completely isolating them, in such a manner as to imit the operation (whether this be section, removal, or irritation) to hem alone. Thus it is impossible to remove them, either separately ›r conjointly, without first removing the Cerebral Hemispheres; and the Thalami cannot be entirely removed, without dividing the stratum of ibres which passes through their deeper portion in their passage to the

Corpora Striata. The evidence afforded by Pathology, too, is far from being self-consistent; and this, it may be surmised, from the circumstance that the effects of morbid changes (particularly of sanguineous effusions) in any part of the Encephalon, extend themselves to other parts than those in which the obvious lesions are found; as is abundantly proved by the great variety of phenomena which present themselves as the results of lesions apparently similar, and the similarity of the phenomena that are frequently consequent upon lesions of very different parts. — The Thalami Optici have not that relation to the visual sense which their designation would imply; for (according to the affirmation of Longet) they may be completely destroyed in Mammals and Birds, without destruction of sight or loss of the activity of the pupil; and irritation of one or both of them produces no contraction of the pupil. It seems probable, therefore, that the loss of sight with dilatation and immobility of the pupil, which is frequently observed in cases of apoplectic effusion into the substance of the Thalami, is really due to the compression of the Optic nerves which lie beneath them. These bodies appear, however, to possess a very decided influence on the power of voluntary movement; for although an animal maintains its balance, and can be made to move onwards, after the removal of the Cerebral Hemispheres, and even after the removal of the Corpora Striata, yet if either of the Thalami Optici be removed, the sensibility and power of voluntary movement are destroyed on the *opposite* side of the body, and the animal consequently falls over to that side (Longet). If, instead of the entire removal of one of the Thalami, an incision be made in it without the previous removal of the Cerebrum, the animal keeps turning to one side in a circular manner (evolution du manège): according to Longet and Lafargue, this movement is directed in the rabbit towards the opposite side; whilst Flourens states that in the frog its direction is towards the injured side; and according to Schiff* the destruction of the three anterior fourths of this organ in the rabbit determines this movement towards the injured side, whilst that of the posterior fourth determines the movement towards the opposite side. No mechanical irritation of the Thalami produces either signs of pain or muscular movement; and this fact might at first appear to negative the doctrine that these organs are the ganglia of common sensation. But it must be borne in mind that the production of pain by mechanical injuries is by no means an universal phenomenon in the case of the nerve-trunks which minister to sensation, the olfactive, optic, and auditory nerves being exempted; and it need occasion still less surprise, therefore, that a nervous *centre* should be destitute of this kind of impressibility.—The effects of lesions of the Corpora Striata are less distinctly marked. It was affirmed by Magendie that there exists in them a motor power, which excites *backward* movement, and that a corresponding power of exciting *forward* movement exists in the Cerebellum; that these two powers ordinarily balance one another; but that, if either organ be removed, the power of the other will occasion a continual automatic movement, the removal of the Corpora Striata causing an irresistible tendency to forward progression, whilst the division of the peduncles of the Cerebellum (according to him) occasions the reverse movement. These assertions, however, have

* Roser's und Wunderlich's "Archiv. für Physiol., Heilkunde," 1846, § 667.

t been confirmed by other experimenters. According to Longet (Op. .), Schiff,* and Lafargue,† the results of removal of the Corpora Striata th the anterior part of the Cerebral hemispheres, are for the most part gative; for the animal usually remains in a state of profound stupor, hough still retaining the erect position; and it is only when irritated pinching or pricking, that it will execute any rapid movements. No echanical irritation of the Corpora Striata produces either signs of pain muscular movement.—No distinct evidence regarding the special funcons of either of these ganglionic masses, can be gained from Pathological ienomena. So far as is yet known, extensive disease of either the ialamus Opticus or the Corpus Striatum of one side produces hemiplegia, paralysis both of sensation and motion, on the opposite side. The same sult very commonly follows an apoplectic effusion into the substance of ther; and although it has been maintained that when the lesion is mited to the Corpus Striatum, the posterior member is peculiarly or one affected, and that lesion of the Thalamus Opticus alone has a special ndency to occasion paralysis of the anterior member, yet the careful ialysis which has been made by Andral ‡ into the pathological phenoiena afforded by seventy-five cases of paralysis in which the apoplectic fusion was limited to one or other of these bodies, does not afford the ast countenance to any such doctrine. And it is affirmed by Longet, iat injury or removal of the Corpus Striatum of one side did not, in his xperiments, affect the posterior more than the anterior limb; nor could e detect any difference in the condition of these limbs after the removal f the Thalamus.

738. When the fibrous tracts which connect these ganglionic masses vith the Medulla Oblongata, and which are commonly (but erroneously) esignated as the *Crura Cerebri*, are completely divided, the result, as night be anticipated, is the annihilation of sensibility and of the power of oluntary movement in the body generally.§ When, however, the Crura Cerebri of a rabbit are not completely divided, but one of them is partially ut through, a little in front of the Pons Varolii, the animal is said by Longet and Schiff to exhibit a constant tendency to turn towards the side opposite to that of the lesion, so that it performs the circular *evolution du manège;* the diameter of its circle of movement being smaller, in proportion as the incision approaches the edge of the Pons. But if one of the Crura be completely divided, the animal then falls over on the opposite side; the limbs of that side being paralysed to the influence of the Encephalic centres, though they may be still caused to exhibit reflex motions. Hence it appears that the circular movements which are performed after incomplete lesions of the Crus Cerebri and Thalamus Opticus of either side, are due to the weakening of the sensori-motor apparatus of the opposite side, whereby the balance of the muscular actions of the two sides is

* "De vi motoriâ baseos encephali," Bockenhemii, 1845.

† "Essai sur la valeur des localisations encéphaliques," &c , Thèse inaug., Paris, 1838.

‡ "Clinique Médicale," tom. ii. p. 664, et seq.

§ It is considered by Longet that these functions are not *completely* destroyed, because the animals on whom this operation has been performed still retain some power of movement, and respond by cries to impressions that ordinarily produce pain. There is no proof, however, that such actions are other than 'excito-motor;' they certainly cannot in themselves be admitted as proving the persistence of consciousness in the lower segment of the Cerebro-Spinal axis.

destroyed. Nearly the same results have been obtained on this point by Longet, Lafargue, and Schiff.—Considerable importance is attached by some Physiologists to the part of the Encephalon known as the *Tuber Annulare*, to which the name of *Mesocephale* has also been given. This is not altogether synonymous with the *Pons Varolii*, as some Anatomists have represented it; for, while the latter consists of transverse fibres, which form the commissure between the hemispheres of the Cerebellum, surrounding and passing between the longitudinal fibres of the Sensory and Motor tracts which constitute the Crura Cerebri, the Tuber Annulare (which exists in animals whose Cerebellum has no hemispheres) is a projection from the surface of the proper Medulla Oblongata, containing a considerable nucleus of vesicular matter. The experiments of Longet have led him to the conclusion that this ganglionic mass is an independent centre of sensation and of motor power; but they do not afford any clear information as to its special attributes. He states, however, that convulsive movements are excited by irritating it, and especially by the transmission of an electric current through its substance. These movements, however, according to the testimony of Dr. Todd, appear to be of a different character from those which are excited by the application of the same stimulus to the Spinal Cord and Medulla Oblongata; for he states that whilst the convulsions excited by the transmission of the current of the magneto-electric machine through the parts just named are *tetanic*, the muscles being thrown into a state of *fixed* contraction,—those which ensue when the current is transmitted through the region of the Mesocephale and Corpora Quadrigemina are *epileptic*, being combined movements of *alternate* contraction and relaxation, flexion and extension, affecting the muscles of all the limbs, of the trunk, and of the eyes, which roll about just as in epilepsy.*

739. *Nerves of Special Sense.*—Having thus taken a general survey of the information supplied by Comparative Anatomy, Experiment, and Pathological phenomena, in regard to the functions of this division of the Encephalon, we shall next inquire into the attributes of the Nerves of which they are obviously the ganglionic centres. — Through the First pair, or *Olfactory* nerves, are transmitted the impressions made by odorous emanations upon the surface it supplies; and it is not susceptible to impressions of any other kind. Anatomical examination of the distribution of this nerve proves that it is not one which directly conveys motor influence to any muscles, since all its branches are distributed to the membrane lining the nasal cavity; and experimental inquiry leads to the same result, for no irritation of the peduncles or branches excites any muscular movement. Further, no irritation of any part of this nerve excites reflex actions through other nerves. Again, it is not a nerve of common sensation; for animals exhibit no sign of pain, when it is subjected to any kind of irritation. Neither the division of the nerve, nor the destruction of the olfactive ganglia, seems to inconvenience them materially. They take their food, move with their accustomed agility, and exhibit the usual appetites of their kind. The 'common' sensibility of the parts contained in the olfactive organ is in no degree impaired, as

* Lumleian Lectures 'On the Pathology and Treatment of Convulsive Diseases,' in "Medical Gazette," May 11, 1849.

shown by the effect of irritating vapours; but the animals are destitute ' the sense of smell, as is shown by the way in which these vapours fect them. At first they appear indifferent to their presence, and then ıddenly and vehemently avoid them, as soon as the Schneiderian mem-ane becomes irritated. Moreover, if two dogs, with the eyes bandaged, ıe having the olfactory nerves and ganglia sound, and the other having ad them destroyed, are brought into the neighbourhood of the dead ody of an animal, the former will examine it by its smell; whilst the ıtter, even if he touches it, pays no attention to it. This experiment 'alentin* states that he has repeated several times, and always with the ıme results. Further, common observation shows that sensibility to ritants, such as snuff, and acuteness of the power of smell, bear no onstant proportion to one another; and there is ample pathological vidence, that the want of this sense is connected with some morbid con-ition of the olfactory nerves or ganglia.—It is well known that Magendie ıas maintained, that the Fifth pair in some way furnishes conditions equisite for the enjoyment of the sense of smell; asserting that, when it s cut, the animal is deprived of this. But his experiments were made vith irritating vapours, which excite sternutation or other violent mus-ular actions, not through the Olfactory nerve, but through the Fifth pair; and the experiments of Valentin, just related, fully prove that the nimals are not sensitive to *odours,* strictly so called, after the Olfactory ıerve has been divided. It is highly probable, however, that the acute-ıess of the true sense of smell may be diminished by section of the Fifth pair; since the Schneiderian membrane is no longer duly moistened by ts proper secretion; and, when dry, it is not so susceptible of the impres-sions made by those minute particles of odoriferous substances, to which he excitement of the sensation must be referred.

740. That the Second pair, or *Optic* nerves, have an analogous charac-ter, appears alike from anatomical and experimental evidence. No chemical or mechanical stimulus of the nerve produces *direct* muscular motion; nor does it give rise, so far as can be ascertained, to indications of pain; whence it may be concluded, that this nerve is not one of common sensation. That the ordinary sensibility of the eyeball remains, when the functions of the Optic nerve are completely destroyed, is well known; as is also the fact, that division of it puts an end to the power of vision. Valentin states that, although the Optic nerve may, like other nerves, be in appearance completely regenerated, he has never been able to obtain any evidence that the power of sight has been in the least degree recovered. He remarks that animals suddenly made blind exhibit great mental disturbance, and perform many unaccustomed movements; and that the complete absence of the power of vision is easily ascertained. Morbid changes are sometimes observed to take place in eyes, whose Optic nerve has been divided; but these are by no means so constant or so extensive, as when the Fifth pair is paralysed; and they may not improbably be attributed to the injury, occasioned by the operation itself, to the parts within the orbit.

741. The Optic nerve, though analogous to the Olfactory in all the points hitherto mentioned, differs from it in one important respect;—that

* "De Functionibus Nervorum Cerebralium," &c., Bernæ, 1839.

it has the power of conveying impressions which excite *reflex* muscular motions. This is especially the case in regard to the Iris, the ordinary actions of which are regulated by the degree of light impinging on the retina. When the Optic nerve is divided, a contraction of the pupil takes place; but this does not occur, if the connection of this nerve with the third pair, through the nervous centres, be in any way interrupted. After such division (if complete), the state of the pupil is not affected by variations in the degree of light impinging on the retina; except in particular cases, in which it is influenced through other channels. Thus, in a patient suffering under amaurosis of one eye, the pupil of the affected eye is often found to vary in size, in accordance with that of the other eye; but this effect is produced by the action of light on the retina of the sound eye, which produces a motor change in the third pair on both sides. Further, as already shown (§ 724), the *impression* only of light upon the retina may give rise to contraction of the pupil, by reflex action, when the optic nerve is itself sound; whilst no *sensations* are received through the eye, in consequence of disease in the sensorial portion of the nervous centres. Although the contraction of the pupil is effected by the influence of motor fibres, which proceed to the sphincter of the Iris from the third pair of nerves, *through* the Ophthalmic ganglion, there is evidence that its dilatation depends rather upon the influence it derived from that ganglion itself, and from the Sympathetic system, of which it forms part.—Some have attempted to show, that the actions of the iris are in a slight degree voluntary, because, by an effort of the will, they could occasion contraction of the pupil; but this so-called voluntary contraction is always connected with a change in the place of the eyeball itself, occasioned by an action of some of its muscles. It is principally noticed under the two following conditions :—1. When an object is brought very near the eye, and we steadily fix our attention upon it, the axes of the two eyes are made to converge; and if this convergence be carried to a considerable extent, so that the pupils of both eyes are sensibly directed towards the inner canthus, a contraction of the pupil takes place. The final cause or purpose of this contraction is very evident. When an object is brought near the eye, the rays proceeding from it would enter the pupil (if it remained of its usual size) at an angle of divergence so much greater than that which would allow them to be properly refracted to a focus, that indistinct vision would necessarily result. By the contraction of the pupil, however, the extreme or most divergent rays are cut off, and the pencil is reduced within the proper angle. The principle is precisely the same, as that on which the optician applies a *stop* behind his lenses, which reduces their aperture in proportion to the shortness of their focal distance. 2. Contraction of the pupil is also noticed, when the eyeball is performing that rotation upwards and inwards, which, when it occurs along with violent respiratory actions, or during sleep, must be regarded as involuntary. (This rotation also takes place, to a slight degree, when the eyelid is depressed, as in ordinary winking; and it is obvious that, in this manner, the surface of the eye is more effectually swept free from impurities which may have gathered upon it, than it would be by the downward motion of the lid alone.) But the pupil is *not* contracted, when the eyeball is *voluntarily* rotated upwards and inwards. Besides the contractions of the pupil, another action of a 'reflex' character is produced through the

Optic nerve,—the contraction of the Orbicularis muscle under the influence of strong light, or when a foreign body is suddenly brought near the eye. But this cannot be produced without a consciousness of the object; in fact, it is a movement of a 'consensual' kind, produced by the painful effect of light, which gives rise to the condition well characterised by the term *photophobia*. The involuntary character of it must be evident to every one who has been engaged in the treatment of diseases of the eyes; and the effect of it is aided by a similarly-involuntary movement of the eyeball itself, which is rotated upwards and inwards, to a greater extent than the Will appears able to effect.—Another reflex movement excited through the visual sense, is that of Sneezing, which is induced in many individuals by the sudden exposure of the eyes to a strong light: of the purely automatic character of this movement there can be no question, since it cannot be imitated voluntarily; and that it is not excito-motor, is proved by the fact that it is not excited unless the light is *seen*.*

742. There is a further peculiarity, of a very marked kind, attending the course of the Optic nerves; this is the crossing or decussation which they undergo, more or less completely, whilst proceeding from their ganglia to the eyes. In some of the lower animals, in which the two eyes (from their lateral position) have entirely different spheres of vision, the decussation is complete; the whole of the fibres from the right optic ganglion passing into the left eye, and *vice versâ*. This is the case, for example, with most of the Osseous Fishes (as the cod, halibut, &c.); and also, in great part at least, with Birds.† In the Human subject, however, and in animals which, like him, have the two eyes looking in the same direction, the decussation seems less complete; but there is a very remarkable arrangement of the fibres, which seems destined to bring the two eyes into peculiarly consentaneous action. The *posterior* border of the Optic Chiasma is formed exclusively of *commissural* fibres, which pass from one *optic ganglion* to the other, without entering the real optic nerve. Again, the *anterior* border of the Chiasma is composed of fibres, which seem, in like manner, to act as a commissure between the two *retinæ;* passing from one to the other, without any connection with the optic ganglia. The tract which lies between the two borders, and occupies the *middle* of the Chiasma, is the true Optic Nerve; and in this it would appear that a portion of the fibres decussates, whilst another portion passes directly from each Optic ganglion into the corresponding eye. The fibres which proceed from the ganglia to the retinæ, and constitute the proper Optic Nerves, may be distinguished into an internal and an external tract. Of these, the *external* on each side, passes directly onwards to the eye of *that* side; whilst the *internal* crosses over to the eye of the *opposite* side. The distribution of these two sets of fibres in the retina of each eye respectively, is such that, according to Mr. Mayo, the fibres from either optic ganglion will be distributed to *its own side* of *both* eyes;‡ the right optic ganglion being thus exclusively connected with the

* A patient was for some time in the London Hospital, in whom there was such an undue impressibility of the retina, that she could not remain in even a moderate light, without a continual repetition of the act of Sneezing.

† See Solly on "The Human Brain," 2nd edit., p. 288.

‡ This arrangement was first hypothetically suggested by Dr. Wollaston ("Philos. Trans.," 1824), as facilitating the explanation of some of the phenomena of vision, and more

outer part of the retina of the right eye, and with the inner part of the retina of the left eye; and the left optic ganglion being, in like manner, connected exclusively with the outer side of the left retina, and with the inner side of the right. Now as either side of the eye receives the images of objects which are on the other side of its axis, it follows, if this account of their distribution be correct, that in Man, as in the lower animals, each ganglion receives the sensations of objects situated on the *opposite* sides of the body. The purpose of this decussation may be, to bring the visual impressions, which are so important in directing the movements of the body, into proper harmony with the motor apparatus; so that, the decussation of the motor fibres in the pyramids being accompanied by a decussation of the optic nerves, the same effect is produced as if neither decussated,—which last is the case with Invertebrated animals in general.

743. The functions of the *Auditory* nerve, or *Portio Mollis* of the 7th, are easily determined, by anatomical examination of its distribution, and by observation of pathological phenomena, to be analogous to those of the two preceding. Atrophy or lesion of the trunk destroys the sense of Hearing; whilst irritation of it produces auditory sensations, but does not occasion pain. From experiments made upon the nerve before it leaves the cranial cavity, it appears satisfactorily ascertained, that this nerve is not endowed either with common sensibility, or with the power of directly stimulating muscular movement. Nor can any obvious reflex actions be executed by irritation of this nerve; but it seems nevertheless by no means improbable, that the muscles which regulate the tension of the Tympanum, are called into action by impressions made upon it and reflected through the auditory ganglion, in the same manner as the diameter of the pupil is regulated through the optic nerve. In the involuntary start, however, which is occasioned by a loud and sudden sound, we have an example of a *consensual* movement excited through the Auditory nerve, which is evidently analogous to the closure of the eyes to a strong light. In certain morbidly-impressible states of the nervous system, as will be shown hereafter, the effect of sounds on the motor apparatus is far more remarkable.—It has been attempted by Flourens to show, that the division of the Auditory nerve, which proceeds to the Semi-circular canals, has functions altogether different from that portion which supplies the Vestibule and Cochlea. This inference, however, is grounded only upon the movements exhibited by animals in which these nerves are irritated; which movements are capable of a different explanation (§ 736).

744. The nerves which minister to the sense of *Taste* are destitute of the peculiarities which distinguish the proceeding; being no other than certain branches of ordinary afferent nerves,—the Fifth Pair and Glosso-pharyngeal (§ 717)—the peculiar endowments of which seem to depend rather upon the structure and actions of the papillæ at their peripheral extremities, than upon anything special in their own characters; for, as

particularly single vision with two eyes. We shall hereafter see, however, that the singleness of the impression resulting from the formation of two pictures upon our retinæ is not attributable to any such anatomical arrangement, their combination being a mental process, and the fusion of two *dissimilar* pictures being requisite to enable us to exercise one of the highest attributes of the visual sense, the perception of *projection*. (See CHAP. XV. Sect. 5).

in the case of the ordinary nerves of 'common' sensation, mechanical irritation applied to them calls forth indications of pain.—From the observations and experiments of M. Cl. Bernard,* it appears that the Facial nerve (portio dura of the 7th) supplies some condition requisite for the sense of Taste, through the branch known as the Chorda Tympani, which is the motor nerve of the Lingualis muscle. When paralysis of the Facial exists in Man, the sense of taste is very much impaired on the corresponding side of the tongue, provided the cause of the paralysis be seated above the origin of the Chorda Tympani from its trunk. Similar results have been obtained from experiments upon other animals. The nature of the influence afforded by this nerve is entirely unknown; and it is the more obscure, as the Chorda Tympani contains no sensory filaments.

745. To the sense of *Touch*, all the afferent nerves of the body (save the nerves of special sense) appear to minister; in virtue—according to the doctrine already propounded—of the direct connection of certain of their fibrils with the *Sensorium commune*. But the degree in which they are capable of producing Sensations, does not bear any constant relation to their power of exciting reflex actions. Thus, the Glosso-pharyngeal is not nearly so *sensitive* as the Fifth pair; though more powerful as an *excitor* nerve. The Par Vagum appears to have even less power of arousing sensory changes; although it is the most important of all the excitors to reflex action. So again, the afferent nerves of the inferior extremities, in Man, are less concerned in ministering to sensations, than are those of the superior; and yet they appear to be much more efficient as excitors to muscular action.—These differences may be accounted for, by supposing that the proportion which the fibres, having their centre in the ganglionic matter of the Spinal Cord, bears to that of the fibres which pass-on to the Sensorium, is not constant, but is liable to variation; the former predominating in the Par Vagum and the Glosso-pharyngeal, whilst the latter are more numerous in the Fifth Pair, and in most of the Spinal nerves.

746. To the reflex actions of the Sensory Ganglia, all the *motor* fibres of the Cranio-spinal axis, save those which originate in its Spinal portion, may be considered as subservient; for, as we have seen, the motor columns from which proceed the anterior roots of the Spinal nerves and the motor Encephalic nerves, pass up into the Corpora Striata and Corpora Quadrigemina; and although the direct connection of the other ganglia of Special Sense with the motor columns is at present a matter of presumption only, yet this presumption is strongly supported by the analogy of the Optic ganglia, the distinctness of the connection in this case being easily accounted-for, when it is remembered in how great a degree the general movements of the body are guided by the visual sense. This anatomical evidence is fully borne-out by the results of experiment; since, as we have seen (§ 738), convulsive movements of all parts of the body may be excited by the application of the electric stimulus to this division of the Encephalic centres.

747. *Functions of the Sensory Ganglia.*—We have now to consider what deductions may be drawn with regard to the functions of the

* "Archives Générales de Médecine," 1844.

Sensory Ganglia in Man, from the facts supplied by Comparative Anatomy, Experimental inquiry, and Pathological phenomena. Here, as in the case of the Spinal Cord, we have to distinguish between their operation as independent ganglionic centres, and their action in subservience to the Cerebrum, which is superposed upon them. We have seen reason to conclude that in their former capacity, they are to be regarded as the true centres of *Sensation* (*i.e.* of the consciousness of external impressions), and as the instrument, in virtue of their own 'reflex' power, of that class of Instinctive or Automatic movements, which require to be prompted and guided by sensations, and which cannot, therefore, be referred to the excito-motor group. But although it is sufficiently obvious that such movements constitute the highest manifestations of Animal life in the Invertebrata generally, and that they are but little modified by any higher principle of action even in the lower Vertebrata, yet it is no less obvious that in adult Man, in whom the Intelligence and Will are fully developed, we have comparatively little evidence of this independent reflex action of the Sensory Ganglia;—all those automatic actions which are *immediately* necessary for the maintenance of his Organic life, being provided for by the excito-motor portion of the apparatus, so that although sensation ordinarily accompanies most of them, it is not essential to them; whilst those which are necessary to provide more *remotely* for its requirements, are for the most part committed to the guidance of his Reason. For the impressions which have been brought by the afferent nerves to his Sensorium, and which have there produced sensations, do not in general react at once upon the motor apparatus (as they do in those animals in which the Sensory Ganglia are the *highest* of the nervous centres), but usually transmit their influence upwards to the Cerebrum, through whose instrumentality they give rise to ideas and reasoning processes, which operate upon the motor apparatus either emotionally or volitionally. And it is for the most part only when this upward transmission is checked, either by the non-development or the functional inactivity of the Cerebrum, or by its complete occupation in some other train of action, — or, on the other hand, when the reflex action of the Sensory ganglia is called into play with unusual potency, — that we have any manifestations of the *sensori-motor* or *consensual* mode of operation in Man, at all comparable in variety or importance to those which are so remarkable in the lower animals.

748. Still, sufficient evidence of the existence of this class of reflex movements may be drawn from observation of the actions of Man in his ordinary condition; examples of it being furnished (as we have seen) by the closure of the eyes to a dazzling light, the start caused by a loud and unexpected sound, or the sneezing excited by sensory impressions on the Schneiderian membrane or the retina. To these may be added the vomiting produced by various sensory impressions, as the sight of a loathsome object, a disagreeable smell, a nauseous taste, or that peculiar feeling of want of support which gives rise to 'sea-sickness,' especially when combined with the sight of continually shifting lines and surfaces, which itself in many individuals disposes to the same state; the involuntary laughter which is excited by tickling, and also that which sometimes involuntarily bursts forth at the provocation of some sight or sound to which no ludicrous idea or emotion can be attached; the yawning which

is excited by an internal sensation of uneasiness (usually arising from deficient respiration) or by the sight or sound of the act as performed by another; and those involuntary movements of the body and limbs, excited by uneasy sensations (probably muscular), which are commonly designated as 'the fidgets.' When the reflex activity of the Sensory ganglia is more strongly excited, in consequence either of an unusual potency of the sensory impressions, or of an unusual excitability of this part of the nervous centres, a much greater variety of sensori-motor actions is witnessed. The powerful involuntary contraction of the orbicularis and of the muscles which roll the eyeball upwards and inwards, in cases of excessive irritability of the retina is one of the best examples of this kind; but another very curious illustration is afforded by the involuntary abridgment of the excito-motor actions of respiration when the performance of these is attended with pain,—the dependence of this abridgment upon the direct stimulus of sensation, rather than upon voluntary restraint, being obvious from the fact that it often presents itself on *one* side only, a limitation which the Will cannot imitate. Again, there are certain Convulsive disorders which appear to depend upon an undue excitability of these centres, the paroxysms being excited by impressions which act through the organs of sense, and are not thus operative unless the patient be conscious of them; thus in Hydrophobia, we observe the immediate influence of the sight, sound, or contact, of liquids, or of the slightest currents of air, in exciting muscular contractions; and in many Hysteric subjects, the sight of a paroxysm in another individual is the most certain means of its induction in themselves. A remarkable case of this general exaltation of purely sensorial excitability has been recorded by Dr. Cowan; who gives the following account of the phenomena, which can scarcely be referred to any other than this category. "The shadow of a bird crossing the window, though the blind and bed-curtains are closed, the displacement of the smallest portion of the wick of a candle, the slightest changes in the firelight, induce a sudden jerking of the spinal muscles, extending to the arms and legs when violent, and this without the slightest mental emotion of any kind beyond a consciousness of the movement. At times the vocal organs are implicated, and a slight cry, quite involuntary, takes place. At these periods she is unusually susceptible of all noises, especially the least expected and least familiar. Movements in the next house inaudible to others, the slightest rattle in the lock of a door, tearing a morsel of paper, and a thousand little sources of sound not to be catalogued, induce results similar to those of visual impressions." *

749. It is, however, when the Cerebrum is not in a state which renders it capable of receiving and acting-upon Sensorial impressions, that we find the independent reflex activity of the Sensory ganglia most strikingly displayed. Thus in the Infant, for some time after its birth, it is obvious to an attentive observer, that a large part of its movements are directly prompted by sensations to which it can as yet attach no distinct ideas, and that they do not proceed from that *purposive* impulse which is essential to render them voluntary. This is well seen in the efforts which it makes to find the nipple with its lips; being probably guided thereto at

* "Lancet," Oct. 4, 1845.

first by the smell, but afterwards by the sight also; when the nipple has been found, the act of suction is purely excito-motor, as already explained. So in the idiot, whose brain has never attained its normal development, the influence of sensations in directly producing respondent movements is obvious to all who examine them with discrimination; and a remarkable case will be cited hereafter (Sect. 7), in which an entire though temporary suspension of Cerebral power, reducing the subject of it to the condition of one of the lowest Vertebrata, gave a very satisfactory proof of the independent power of this division of the Encephalic centres.—But we do not require to go so far in search of characteristic examples of this kind of reflex action; since they are afforded, as already remarked, by the performance of *habitual* movements, which are clearly under Sensorial guidance, when the Cerebrum is occupied in some train of action altogether disconnected with them. An individual who is subject to 'absence of mind,' may fall into a reverie whilst walking the streets; his whole attention may be absorbed in his train of thought, and he may be utterly unconscious of any interruption in its continuity; and yet, during the whole of that time, his limbs shall have been in motion, carrying him along the accustomed path, whilst his vision shall have given the direction to these movements, which is requisite to guide him along a particular line, or to move him out of it for the avoidance of obstacles. As already remarked (§ 726), there seems strong reason for regarding the ambulatory movements of the limbs as in themselves excito-motor; but the guidance of these movements by the visual sense marks the participation of the Sensorium in this remarkable performance. It has been maintained by some Metaphysicians and Physiologists that these 'secondarily automatic' actions always continue to be voluntary, because their performance is originally due to a succession of volitional acts, and because, in any particular case, it is the will which first excites them, whilst an exertion of the will serves to check them at any time. But this doctrine involves the notion, that the will is in a state of pendulum-like oscillation between the train of thought and the train of movement; whereas nothing is more certain to the individual who is the subject of both, than that the former may be as uninterrupted as if his body were perfectly at rest, and his reverie were taking place in the quietude of his own study. And as it commonly happens that the direction taken is that in which the individual is most in the habit of walking, it will not unfrequently occur that if he had previously intended to pursue some other, he finds himself, when his reverie is at an end, in a locality which may be very remote from that towards which his walk was originally destined; which would not be the case, if his movements had been still under the purposive direction of the will. And although it is perfectly true that these movements can be at any time checked by an effort of the will, yet this does not really indicate that the will has been previously engaged in sustaining them; since, for the will to act upon them at all, the *attention* must be recalled to them, and the Cerebrum must be liberated from its previous self-occupation. And the gradual conversion of a volitional into an automatic train of movements, so that at last the train, once started, shall continue to run down of itself, will be found to be less improbable than it would at first appear, when it comes to be understood that the mechanism of both sets of actions is essentially the same, and that they

merely differ as regards the nature of the stimulus which originally excites them (§ 757). That the same automatic movements are not excited by the same sensations, when the Cerebrum is in its ordinary state of functional connection with the Sensorium, is a fact entirely in harmony with the principle already laid down (§§ 683—6). The complete occupation of the mind in other ways, as in close conversation or argument, or even (it may be) in the voluntary direction of some other train of muscular movements, is no less favourable than the state of reverie, to that independent action of the Automatic centres which has been now described.

750. In the state of entire functional activity of the nervous centres of Man, however, there can be no doubt that the operation of the Sensory Ganglia is entirely subordinated to that of the Cerebrum; and that it furnishes an essential means of connection between the actions of the Cerebrum on the one hand, and those of the organs of Sense and Motion on the other, by the combination of which the Mind is brought into relation with the external world. For, in the first place, it may be affirmed with certainty that no mental action can be excited in the first instance, save by the stimulus of Sensations; and it is the office of the Sensory ganglia to form these out of the impressions brought to them from the organs of sense, and to transmit such sensorial changes to the Cerebrum. But they have a no less important participation in the downward action of the Cerebrum upon the motor apparatus; for no voluntary action can be performed without the assistance of a *guiding sensation*, as was first prominently stated by Sir C. Bell.*—In the majority of cases, the guiding or controlling sensation is derived from the muscles themselves, of whose condition we are rendered cognizant by the sensory nerves with which they are furnished; but there are certain cases in which it is ordinarily derived from one of the special senses, and in which the muscular sense can only imperfectly supply the deficiency of such guidance; whilst, again, if the muscular sense be deficient, one of the special senses may supply the requisite information. The proof of this necessity is furnished by the *entire impossibility of making or sustaining voluntary efforts, without a guiding sensation of some kind.* Thus, in complete anæsthesia of the lower extremities, without loss of muscular power, the patient is as completely unable to walk, as if the motor nerves had also been paralysed, unless the deficient sensorial guidance be replaced by some other; and in similar affections of the upper extremities, there is a like inability to raise the limb or to sustain a weight. But in such cases, the deficiency of the "muscular sense" may be made good by the visual; thus, the patient who cannot feel either the contact of his foot with the ground, or the muscular effort he is making, can manage to stand and walk if he *look* at his limbs; and the woman who cannot feel the pressure of her child upon her arms, can yet sustain it as long as she keeps her eyes fixed upon it, but no longer,—the muscles ceasing to contract, and the limb dropping powerless, the moment that the eyes are withdrawn from it. Thus it is, too, that when we are about to make a muscular effort, the amount of force which we put forth is governed by the mental conception of that which will be required, as indicated by the

* See his chapter 'On the Nervous Circle which connects the voluntary muscles with the Brain,' in his work "On the Nervous System of the Human Body."

experience of former sensations; just as the contractions of the muscles of vocalization are regulated by the conception of the sound to be produced. Hence if the weight be unknown to us, and it prove either much heavier or much lighter than was expected, we find that we have put forth too little or too great a muscular effort.

751. There are two groups of muscular actions, however, which, although as voluntary in their character as the foregoing, are yet habitually guided by other sensations than those derived from the muscles themselves. These are, the movements of the *eyeball*, and those of the *vocal apparatus.*—The former are directed by the visual sense,* by which the action of the muscles is guided and controlled, in the same manner as that of other muscles is directed by their own 'muscular sense;' and hence it happens that, when we close our eyes, we cannot move them in any required direction, without an effort that strongly calls forth the muscular sense, by which the action is then guided. In persons who have become blind after having once enjoyed sight, an association is formed by habit between the muscular sense and the contractile action, that enables the former to serve as the guide after the loss of the visual sense; but in those who are born *perfectly* blind, or who have become so in early infancy, this association is never formed, and the eyes of such persons exhibit a continued indefinite movement, and cannot by any amount of effort be steadily fixed in one spot, or be turned in any definite direction. A very small amount of the visual sense, however, such as serves merely to indicate the direction of light, is sufficient for the government of the movements of the eye-ball.—In the production of vocal sounds, again, that nice adjustment of the muscles of the larynx, which is requisite to give forth determinate tones, is ordinarily directed by the auditory sense: being learned in the first instance under the guidance of the sounds actually produced; but being subsequently effected voluntarily, in accordance with the mental conception (a sort of inward sensation) of the tone to be uttered, which conception cannot be formed, unless the sense of hearing has previously brought similar tones to the mind. Hence it is that persons who are born *deaf*, are also *dumb*. They may have no malformation of the organs of speech; but they are incapable of uttering distinct vocal sounds or musical tones, because they have not the guiding conception, or recalled sensation, of the nature of these. By long training, however, and by imitative efforts directed by muscular sensations in the larynx itself, some persons thus circumstanced have acquired the power of speech; but the want of a sufficiently definite control over the vocal muscles is always very evident in their use of the organ. It is very rarely that a person who has once enjoyed the sense of hearing, afterwards becomes so *completely* deaf, as to lose all auditory control over his vocal organs. An example of this kind, however, has been made known to the public by a well known author, as having occurred in himself; and the record of his experiences† contains many points of much interest. The deafness was the result of an accident occurring in childhood, which left him for some time in a state of extreme debility; and when he made the attempt to speak, it was with considerable pain in the vocal organs. This pain pro-

* See Dr. Alison's Memoir on the 'Anatomical and Physiological Inferences from the Study of the Nerves of the Orbit,' in "Trans. of Roy. Soc. of Edinb.," vol. xv.

† See the "Lost Senses," by Dr. Kitto; vol. i., chapters 2 and 3.

ably resulted from the unaccustomed effort which it was necessary to make, when the usual guidance was wanting; being analogous to the uneasiness which we experience, when we attempt to move our eyes with the lids closed. His voice at that time is described as being very similar to that of a person born deaf and dumb, but who has been taught to speak. With the uneasiness in the use of the vocal organs was associated an extreme mental indisposition to their employment; and thus, for some years, the voice was very little exercised. Circumstances afterwards forced it, however, into constant employment; and great improvement subsequently took place in the power of vocalization, evidently by attention to the indications of the muscular sense. It is a curious circumstance fully confirming this view, that the words which had been in use previously to the supervention of the deafness, are still pronounced (such of them, at least, as are kept in employment) as they had been in childhood; the muscular movements concerned in their articulation being still guided by the original auditory conception, in spite of the knowledge derived from the information of others, that such pronunciation is erroneous. On the other hand, all the words subsequently learned are pronounced according to their spelling; the acquired associations between the muscular sensations and the written signs being in this case the obvious guide.

752. It is through the muscular sense, in combination with the visual and tactile, that those movements are regulated, which are concerned alike in ordinary progression, and in the maintenance of the equilibrium of the body. That the visual sense has, in most persons, a large share in this regulation, is evident from the simple fact, that no one who has not been accustomed to the deprivation of it can continue to walk straightforwards, when blind-folded, or in absolute darkness, towards any point in the direction of which he may have been at first guided. But the blind man, who has been accustomed to rely exclusively upon his muscular sense, has no difficulty in keeping to a straight path; and moves onwards with a confidence which is in remarkable contrast with the gait of a man who has been deprived of sight for the occasion only. In fact, as Mr. Mayo has well remarked,* in our ordinary movements, "we lean upon our eyesight as upon crutches." And when our vision, instead of aiding and guiding us, brings to the mind sensations of an antagonistic character, our movements become uncertain, from the loss of that power of guidance and control over them, which the harmony of the two sensations usually gives. Thus a person unaccustomed to look down heights *feels* insecure at the top of a tower or a precipice, although he *knows* that his body is properly supported; for the void which he sees below him contradicts (so to speak) the tactile sensations by which he is made conscious of the due equilibrium of his body. So, again, any one can walk along a narrow plank which forms part of the floor of a room, or which is elevated but a little above it, without the least difficulty, and even without any consciousness of effort. But let that plank extend across a chasm, the bottom of which is so far removed from the eye that the visual sense gives no assistance; and even those who have braced their nerves against all emotional distraction, feel that an effort is requisite to maintain the equilibrium during their passage over it; that effort being aided

* "Outlines of Physiology," p. 355.

by the withdrawal of the eyes from the abyss below, and the fixation of them on a point beyond, which at the same time helps to give steadiness to the movements, and distracts the mind from the sense of its danger. The degree in which the muscular sense is alone sufficient for the guidance of such movements, when the mind has no consciousness of the danger, and when the visual sense neither affords aid nor contributes to distract the attention, is remarkably illustrated by the phenomena of Somnambulism; for the sleep-walker traverses, without the least hesitation, the narrow parapet of a house, and crosses narrow and insecure planks, clambers roofs, &c., under circumstances that clearly indicate the nature of the guidance by which he is directed (see Sect. 7).—The dependence of our ordinary power of maintaining our equilibrium, upon the combination of the guiding sensations derived through the sight and the touch, is further well illustrated, as Mr. Mayo has pointed out (loc. cit.), by what happens to a landsman on first going to sea. "It is long before the passenger acquires his 'sea legs.' At first, as the ship moves, he can hardly keep his feet; the shifting lines of the vessel and surface of the water unsettle his visual stability; the different inclinations of the planks he stands on, his muscular sense. In a short time, he learns to disregard the shifting images and changing motions, or acquires facility in adapting himself (like one on horseback) to the different alterations in the line of direction in his frame." And when a person who has thus learned by habit to maintain his equilibrium on a shifting surface, first treads upon firm ground, he feels himself almost as much at fault as he did when he first went to sea; and it is only after being some time on shore, that he is able to resume his original manner of walking. Indeed, most of those who spend the greater part of their time at sea, acquire a peculiar gait, which becomes so habitual to them, that they are never able to throw it off.

753. But further, there is very strong physiological evidence, that the Sensory Ganglia are not merely the instruments whereby our voluntary movements are directed and controlled, in virtue of the guiding sensations which they furnish, but that they are actually the immediate centres of the motor influence which excites muscular contractions, in obedience to impulses transmitted downwards from the Cerebrum. It has usually been considered that the Cerebrum acts directly upon the muscles through the motor nerves, in virtue of a direct continuity of fibres from the grey matter of its convolutions, *through* the Corpora Striata, the motor tract of the Medulla Oblongata, the anterior portion of the Spinal Cord, and the anterior roots of the nerves; and that in the performance of any voluntary movement, the Will determines the motor force to the muscle or set of muscles by whose instrumentality it may be produced. To this doctrine, however, the anatomical facts already stated (§ 730) constitute a very serious objection; for the motor tract cannot be stated with certainty to have any higher origin than the Corpora Striata; and it is impossible to imagine that the fibres which converge towards the surface of these bodies from all parts of the Cerebrum, can be so closely compacted together as to be included in the motor columns of the Spinal Axis. The fact would rather seem to be, that these converging fibres bear the same kind of anatomical relation to the Corpora Striata and the other Sensorial centres of motor power, as do the fibres of

afferent nerves which proceed to them from the Retina, the Schnei-ian membrane, and other peripheral expansions of nervous matter; l hence we might infer that the nerve-force generated in the convolu-ns, instead of acting *immediately* on the motor nerves, is first directed vards the Automatic centres, and excites the same kind of motor re-onse in them, as would be given to an impression transmitted to them rough a sensory nerve. We shall find that such a view of the struc-ral arrangements of these parts is in remarkable accordance with their ictional relations, as indicated by a careful analysis of the mechanism of iat is commonly regarded as voluntary movement. The Cerebrum, as ll be shown hereafter (Sect. 5), may thus call the Automatic apparatus o action, as the instrument either of *ideas*, of *emotions*, or of *volitional terminations;* but as both the *ideo-motor* and the *emotional* movements ve much in common with the automatic, there is no occasion for at esent specially inquiring into their mechanism, and we may limit our amination to *voluntary* movements alone, which have been usually garded as in such complete antagonism to those of the automatic group, at even distinct sets of nerve-fibres have been thought requisite to count for the transmission of these two sets of motor impulses to e muscles.

754. Now in the first place it may be asserted with some confidence, at no effort of the Will *can* exert that direct influence on the muscles, iich our ordinary phraseology, and even the language of scientific asoners, would seem to imply; but, on the other hand, that the Will is lely concerned in determining the *result*, the selection and combination muscular movements required to bring about this result *not* being ected by the Will, but by some intermediate agency. If it were other-se, we should be dependent upon anatomical knowledge for our power performing the simplest movement of the body; whereas we find the t to be, that the man who has not the least idea of the mechanism of uscular action can acquire the most perfect command over his move-ents, and can adapt them as perfectly to the desired end as the most complished anatomist could do. Further, we cannot, by any exertion the will, single-out a particular muscle and throw it into contraction itself, unless that muscle be one which is alone concerned in an tion that we can voluntarily perform; and even then we single it out *willing* the action. Thus we can put the *levator palpebræ* in action by self; but this we do, not by any conscious determination of power to e muscle itself, but by *willing* to raise the eyelids; and it is only by r anatomical knowledge, that we know that but a single muscle is con-rned in this movement. So far as our own consciousness can inform us, ere is no difference between the mechanism of this action and that of e flexion of the knee or elbow joint; and yet in these latter movements, veral muscles are concerned, not one of which can be singled-out by an fort of the will, and thrown into action separately from the rest.—The ea that the will is *directly* exerted upon the muscles called into action produce a particular movement, may seem to derive some support om the *sense of effort* of which we are conscious in making the exertion, d which we refer to the muscles which are concerned in it; but this nse of effort is nothing else than the 'muscular sense' already alluded , which has its origin in the state of tension of the muscles, and which

is no more an indication of *mental* effort directed to them, than the sensation of light or sound is an indication of a determination of voluntary power to the eyes or ears.

755. There are two cases in which it is very easy to show that the Will is concerned with the result alone, and is not directly exerted upon the instruments by which that result is brought about. These are, the movements of the Eyes, and the production of Vocal tones. In neither of these are we conscious of any effort in the muscular apparatus, unless the contraction be carried beyond its accustomed extent; the ordinary movements being governed, as already remarked, not by the muscular sense, but by the visual and auditory senses respectively.—Nothing can be more simple, to all appearance, than the act of turning the eyes upwards or downwards, to one side or the other, in obedience to a determination of the Will; and yet the Will does not impress such a determination upon the muscles. That which the Will really does, is to cause the eye-ball to roll in a given direction, in accordance with a visual sensation; and it is only *when there is an object* towards which the eyes can be turned, that we can move them with our usual facility. When the eyelids are closed, and we attempt to roll the globes upwards or downwards, to one side or the other, we feel that we can do so but very imperfectly, and with a sense of effort referred to the muscles themselves,—this sense being the result of the state of tension in which the muscles are placed, by the effort to move the eyes without the guiding visual sensation. Now, on the other hand, the Will may determine to fix the eyes upon an object; and yet this very fixation may be only attainable by a muscular movement,—which movement is directly excited by the visual sense, without any exertion of voluntary power over the muscles. Such is the case when we look steadily at an object, whilst we move the head horizontally from side to side; for the eyeballs will then be moved in the contrary direction by a kind of instinctive effort of the external and internal recti, which tends to keep the retinæ in their first position, and to prevent the motion of the images over them. So, when we look steadily at an object, and incline the head towards either shoulder, the eyeballs are rotated upon their antero-posterior axis (probably by the agency of the oblique muscles) apparently with the very same purpose,—that of preventing the images from moving over the retinæ. Now we cannot refuse to this rotation any of the attributes which really characterize the so-called voluntary movements; and yet we are not even informed by our own consciousness that such a movement is taking place, and know it only by observation of others.

756. The muscular contractions which are concerned in the production of vocal tones, are, in like manner, always accounted voluntary; and yet it is easy to show that the Will has no direct power over the muscles of the larynx. For we cannot raise or depress the larynx as a whole, nor move the thyroid cartilage upon the cricoid, nor separate or approximate the arytenoid cartilages, nor extend or relax the vocal ligaments, by simply *willing* to do so, however strongly. Yet we can readily do any or all these things, by an act of the Will exerted for a specific purpose. We conceive of a tone *to be* produced, and we *will* to produce it; a certain combination of the muscular actions of the larynx then takes place, in most exact accordance one with another; and the predetermined tone is the

ult. This anticipated or conceived sensation is the guide to the mus-ar movements, when as yet the utterance of the voice has not taken ce; but whilst we are in the act of speaking or singing, the contractile ions are regulated by the present sensations derived from the sounds they are produced. It can scarcely but be admitted, then, that the ll does *not* directly govern the movements of the Larynx; but that se movements are immediately dependent upon some other agency.

757. Now what is true of the two preceding classes of actions, is ually true of all the rest of the so-called *voluntary* movements; for in of them the power of the Will is really limited to the determination of e result; and the production of that result is entirely dependent upon e concurrence of a 'guiding sensation,' which is usually furnished by the ry muscles that are called into action. It is obvious, therefore, that we ve to seek for some intermediate agency, which *executes* the actions *termined* by the Will; and when the facts and probabilities already ted are duly considered, they tend strongly in favour of the idea, that en Voluntary movements are executed by the instrumentality of the itomatic apparatus, and that they differ only from the automatic or stinctive in the nature of the stimulus by which they are excited,—the termination of the Will here replacing, as the *exciting cause* of its action, e sensory impression which operates as such in the case of an instinctive ovement, and which is still requisite for its guidance.

758. This view of the case derives a remarkable confirmation from the alysis of two classes of phenomena; the first consisting of cases in hich movements that are ordinarily automatic are performed by volun-ry determination, or simply in respondence to an idea; the second nsisting of those in which movements originally voluntary come by bit to be automatically performed.—Of the first class, the act of Cough-g is a good example. This action, which is ordinarily automatic, may so be excited by a voluntary determination; such a determination, wever, is directed to the *result*, rather than exercised in singling-out e different movements and then combining them in the necessary quence; and it thus seems obviously to take the place of the laryngeal tracheal irritation, as the *primum mobile* of the series, which, in its tual performance, is as automatic in the latter case as in the former. , again, we know that many of the automatic movements which have en already referred-to as examples of the sensori-motor group (§ 748), d which the Will cannot call forth, may be performed in respondence *ideas* or *conceptions*, which are Cerebral states that seem to recal the me condition of the Sensorium as that which was originally excited by e Sensory impression. Thus it is well known that the act of Vomiting ay be induced by the *remembrance* of some loathsome object or nause-us taste, which may have been excited by some act of 'suggestion;' and e author has known an instance in which a violent fit of sea-sickness as brought on by the sight of a vessel tossed about at sea, which recalled e former experience of that state. So, the Hydrophobic paroxysm may e excited by the mention of the *name* of water, which of course calls up e idea; and a tendency to yawn is in like manner frequently induced y looking at a picture of yawners, or by speaking of the act, or by oluntarily commencing the act, which may then be automatically com-eted. — The automatic performance of actions which were originally

voluntary, has already been fully discussed (§ 749); and we have therefore only to remark here, that the fact very strongly supports the view now advanced, as to the *singleness* of the mechanism which serves as the instrument of both classes of actions, and the essential uniformity of its operation in the two cases.—It would be difficult to explain either set of phenomena satisfactorily, on the hypothesis that there is a "distinct system" of fibres for the volitional and for the automatic movements; since it is not readily to be conceived how a set of movements originally performed by the one, can ever be transferred to the other; whilst, on the other hand, it is easy to understand how the same motorial action may be excited in the automatic centres, either by an *external* impression conveyed thither by an afferent nerve from a Sensory surface (as that of the irritation in the air-passages, which excites the act of coughing), or by a stimulus proceeding from the convoluted surface of the Cerebrum, and conveyed along those connecting fibres which Reil with great sagacity termed the "nerves of the *internal* senses."

759. To sum up, then, we seem justified in concluding that the *Cranio-Spinal Axis* of Man and other Vertebrata,—consisting of the Sensory Ganglia, Medulla Oblongata, and Spinal Cord,—is (like the chain of cephalic and ventral ganglia of Articulata with which it is homologous) the immediate instrument of *all sensorial and motor changes;* that by its sole and independent action are produced all those movements which are ranked as automatic or *instinctive,* these being performed in respondence to external impressions which may or may not affect the consciousness; but that when acting in subordination to the Cerebrum, the Cranio-Spinal Axis transmits upwards to it the influence of Sensorial changes, and receives from it the downward impulses, which it directs automatically into the appropriate channel for the execution of the movements which the Mind has directed. The number of purely automatic actions diminishes in proportion to the development of the Cerebrum, and to the subjection of the Automatic apparatus to its control; but even in Man, those most closely connected with the maintenance of the organic functions, or most necessary for the conservation of the bodily structure, remain quite independent of any mental agency, and most of them do not require consciousness for their excitation. But when the activity of the Cerebrum is suspended or is otherwise directed, without any affection of the automatic apparatus, movements which have long been habitually performed in a particular sequence, may be kept up, when the will has once set them in action, through the automatic mechanism alone; the impressional or sensational change produced by each action, supplying the stimulus which calls forth the next.—It may further be concluded, that the Sensory Ganglia, which are the instruments whereby we are rendered *conscious* of external impressions, are also the seat of those simple *feelings* of pleasure and pain, which are immediately linked-on to that consciousness. For it can scarcely be doubted that such feelings must be associated with particular sensations, in animals that have no ganglionic centres above these; since we must otherwise regard the whole series of Invertebrated tribes as neither susceptible of enjoyment, nor capable of feeling pain or discomfort. And it is scarcely probable that a state of consciousness which we can scarcely ourselves distinguish from the sensation that induces it, should have a separate centre in our Encephalon.

### 4. *Of the Cerebellum, and its Functions.*

760. The Cerebellum is an organ which, though confined to the Vertebrated sub-Kingdom, is yet in peculiarly intimate relation with the Automatic apparatus. In that highest state of development which it presents in Man, we find it to consist of two *lateral* lobes or *hemispheres*, composed of nerve-fibres invested in a very peculiar manner by vesicular substance, and of a *central* lobe, also containing a combination of the vesicular and fibrous substances, which is known under the designation of the 'vermiform process.' The hemispheres are not only connected with each other by this central lobe, but also by the fibrous commissure which passes beneath the Medulla Oblongata, and is known as the 'Pons Varolii.' The commissural fibres form part of the 'Crura Cerebelli;' but another portion is formed by the strands which connect the Cerebellum with the anterior and posterior columns of the Spinal Cord and Medulla Oblongata (§ 711); and in addition to these, we find a fasciculus of fibres passing between the Cerebellum and the Corpora Quadrigemina, the 'iter a cerebello ad testes.' The peduncle of its hemispheres on either side contains a mass of grey matter, which seems to be a ganglionic centre for the fibres that pass upwards to it from the Spinal Axis. Thus the Cerebellum has no direct connection with the Cerebrum, and its relations are entirely with the Automatic apparatus.

761. When we examine into the relative development of the Cerebellum in the different classes of Vertebrata, we find that it presents some very remarkable differences.* In its simpler forms, this organ is found to consist entirely of the representative of the *central* lobe of the Human Cerebellum, the hemispheres not making their appearance until we have ascended to the class of Birds. The proportional development of the Cerebellum is smallest in the Vermiform Fishes, which approach most nearly to the Invertebrata; but it is much greater in the higher Cartilaginous Fishes, than it is in Reptiles, in which it is generally very low. Passing on to Birds, we remark that the average dimensions of the Cerebellum greatly surpass those of the organ in Reptiles; but that they do not exceed those occasionally met with in Fishes. The greatest size is not found in those species, which approach most nearly to the Mammalia in general conformation, such as the Ostrich; but in those of most active and varied powers of flight. Lastly, on ascending the scale of Mammiferous animals, we cannot but be struck with the rapid advance in the proportional size of the Cerebellum, which we observe as we rise from the lowest (which are surpassed in this respect by many Birds) towards Man, in whom it attains a development which appears enormous, even when contrasted with that of the Quadrumana.—Now on looking at the size of the Cerebellum in relation to the general motor activity of these classes respectively, and especially taking into account the *variety* of their respective movements, and the number of separate muscular actions which are combined in each, we can scarcely help noticing that it is in the tribes which are most distinguished in these respects, that the largest Cerebellum is usually

* The fullest information upon this point will be found in M. Serres's "Anatomie Comparée du Cerveau," and M. Leuret's "Anat. Comp. du Système Nerveux."

found. Thus, of all classes of Vertebrata, Reptiles are the most inert; and their motions require the least co-ordination. The active predaceous Sharks far surpass them in this respect, and may be compared with Birds, in the energy of their passage through the water, and in their facility of changing their direction during the most rapid progression; their Cerebellum, accordingly, bears to their Spinal Cord very much the same proportion as it does in Birds. On the other hand, the Flat Fish, which lie near the bottom of the ocean, and which have a much less variety of movement, have a very much smaller Cerebellum; and the Vermiform Fishes, which are almost all completely destitute of fins, and whose motions resemble those of the lower Articulata, have a Cerebellum so small as to be scarcely discoverable. On looking at the class of Birds, we observe that the active predaceous Falcons, and the swift-winged Swallows (the perfect control possessed by which over their complicated movements must have been observed by every one), have a Cerebellum much larger in proportion than that of the Gallinaceous birds, whose powers of flight are small, or than that of the Struthious tribe, in which they are altogether absent. Lastly, on comparing its proportional size in the different orders of Mammalia, with the number and variety of muscular actions requiring combined movements, of which they are respectively capable, we observe an even more remarkable correspondence. In the hoofed Quadrupeds, in which the muscular apparatus of the extremities is reduced to its greatest simplicity, and in which the movements of progression are simple, the Cerebellum is relatively smaller than it is found to be in some Birds; but in proportion as the extremities acquire the power of prehension, and together with this a power of application to a great variety of purposes,—still more, in proportion as the animal becomes capable of maintaining the erect posture, in which a constant muscular exertion, consisting of a number of most elaborately-combined actions, is required,—do we find the size of the Cerebellum, and the complexity of its structure, undergoing a rapid increase. Thus, even between the Dog and the Bear there is a marked difference; the latter being capable of remaining for some time in the erect posture, and often spontaneously assuming it; whilst to the former it is anything but natural. In the semi-erect Apes, again, there is a very great advance in the proportional size of the Cerebellum; and those which most approach Man in the tendency to preserve habitually the erect posture, also come nearest to him in the dimensions of this organ.

762. Now it is evident that Man, although far inferior to many of the lower animals in the power of performing various particular kinds of movement, far surpasses them all in the number and variety of the combinations which he is capable of executing, and in the complexity of the combinations themselves. Thus, if we attentively consider the act of *walking* in man, we shall find that there is scarcely a muscle of the trunk or extremities which is not actively concerned in it; some being engaged in performing the necessary movements, and others in maintaining the equilibrium of the body, which is disturbed by them. On the other hand, in the Horse or Camel, the muscular movements are individually numerous, but they do not require nearly the same perfect co-ordination. And in the Bird, the number of muscles employed in the movements of flight, and in directing the course of these, is really comparatively small; as may at

once be perceived, by comparing the rigidity of the skeleton of the trunk of the Bird with that of Man, and by remembering the complete inactivity of the lower extremities during the active condition of the upper. In fact, the motions of the wings are so simple and regular, as to suggest the idea, that, as in Insects, their character is more automatic than directly voluntary:—an idea which is supported by the length of time during which they can be kept up without apparent fatigue, and also by the important facts already mentioned, which experimental research has disclosed (§ 734).

763. We have next to inquire what evidence can be drawn from Experimental investigations on the same subject: and in reference to this it is desirable to remark, in the first place, that the experimental mode of inquiry is perhaps more applicable to this organ than to other parts of the Encephalon; inasmuch as it can be altogether removed, with little disturbance of the actions immediately essential to life; and the animals soon recover from the shock of the operation, and seem but little affected, except in some easily-recognized particulars. The principal experimenters upon this subject have been Rolando, Flourens, Magendie, Hertwig, and Longet. It is not to be expected, that there should be an exact conformity among the results obtained by all. Every one who has been engaged in physiological experiments, is aware of the amount of difference caused by very minute variations in their circumstances; in no department of inquiry is this more the case, than in regard to the Nervous System; and such differences are yet more likely to occur, in experiments made upon its centres, than in those which concern its trunks.— The investigations of Flourens are the most clear and decisive in their results; and of these we shall accordingly take a general survey. He found that, when the Cerebellum was mechanically injured, the animals gave no signs of sensibility, nor were they affected with convulsions. When the Cerebellum was being removed by successive slices, the animals became restless, and their movements were irregular; and by the time that the last portion of the organ was cut away, the animals had entirely lost the power of springing, flying, walking, standing, and preserving their equilibrium,— in short, of performing any combined muscular movements, which are not of a simply-reflex character. When an animal in this state was laid upon the back, it could not recover its former posture; but it fluttered its wings and did not lie in a state of stupor. When placed in the erect position, it staggered and fell like a drunken man,—not, however, without making efforts to maintain its balance. When threatened with a blow, it evidently saw it, and endeavoured to avoid it. It did not seem that the animal had in any degree lost voluntary power over its several muscles; nor did sensation appear to be impaired. The faculty of *combining* the actions of the muscles in groups, however, was completely destroyed; except so far as those actions (as that of Respiration) were dependent only upon the reflex function of the Spinal Cord. The experiments afforded the same results, when made upon each class of Vertebrated animals; and they have since been repeated, with corresponding effects, by Bouillaud and Hertwig. The latter agrees with Flourens, also, in stating that the removal of one side of the Cerebellum affects the movements of the opposite side of the body; and he further mentions that, if

the mutilation of the Cerebellum have been partial only, its function is in great degree restored.*

764. It was further affirmed by Magendie, that the removal of the Cerebellum, or the infliction of a deep wound of its substance on both sides, occasions the animal to move *backwards* as if by an irresistible impulse; and this he attributed to the retrograde power of the Corpora Striata, which now acts without its due balance. That such a movement does *sometimes* present itself after such injuries as have been described, cannot be questioned, the fact having been confirmed by other experimenters; but it is a phenomenon of such rarity, that it cannot be rightly considered as having any direct dependence upon the injury of the Cerebellum, but must be rather set down to some accidental complication or concurrent disturbance; more especially since, as already pointed out (§ 737), the function attributed by Magendie to the Corpora Striata has no real existence.—But the results of section of one of the Crura Cerebelli, which were first obtained by Magendie, are much more constant; for the performance of this operation causes the animal to fall over upon one side, and to continue *rolling upon its longitudinal axis*, even as fast (in some instances) as sixty times in a minute, the movement going on for many days without intermission. There is a remarkable difference in the statements of different experimenters, however, as regards the direction of this rolling movement; for whilst Magendie and Müller affirm that it takes place *towards* the injured side, Longet and Lafargue assert that it takes place *from* the injured side towards the opposite side. This discrepancy appears, from the experiments of Schiff,† to be due to a difference in the locality of the section; for he states that if the peduncle be divided from *behind*, the animal turns *towards* the side on which the section is made; whilst if the section be made *in front*, the animal turns *from* that side towards the opposite one. This difference is explained by Longet, by the difference in the course of the anterior and posterior fibres of the peduncles; for according to him the former communicate with the decussating, and the latter with the non-decussating portion of the motor tract; so that, when the former are injured, the animal loses control over the muscles of the opposite side, and when the latter, over the muscles of the same side. This rolling movement is attributed by some to the continued activity of the muscles of one side, now unbalanced by that of the muscles on the other; but if such were the case, as Longet justly remarks, it ought to occur more frequently than it does in cases of ordinary hemiplegia; and, according to that experimenter, observation shows that it rather depends on a *twisting* movement of the spinal column, especially affecting its anterior portion, and dragging the posterior (as it were) after it.‡

765. The information supplied by Pathological phenomena, when inter-

* All these results are objected to by those who assert that the Cerebellum is the seat of the sexual instinct, on the ground that the observed aberrations of the motor functions are sufficiently accounted for, by the general disturbance which an operation so severe must necessarily induce. The fallacy of this objection, however, is shown by the fact, that the much more severe operation of removing the Hemispheres does not occasion such an aberration; the power of performing the associated movements, and of maintaining the equilibrium, being remarkably preserved after the loss of them (§ 734).

† "De vi motoriâ baseos encephali inquisitiones experimentales;" Bockenhemii, 1845.

‡ See his "Traité de Physiologie," tom. ii. partie 2, pp. 216, 217.

preted with the cautions formerly referred-to, is found on the whole to coincide with that obtained from experiment. In the first place, it fully supports the conclusion that the Cerebellum is not in any way the instrument of *psychical* operations. Inflammation of the membranes covering it, if confined to that part, does not produce delirium; and its almost complete destruction by gradual softening, does not appear necessarily to involve loss of intellectual power. "But," remarks Andral, "whilst the changes of intelligence were variable, inconstant, and of little importance, the lesions of motion, on the contrary, were observed in all the cases [of softening] except one; and in this it is not quite certain that motion was not interfered with." Yet the result of Andral's analysis of as many as ninety-three cases of disease of the Cerebellum,* is not favourable to the doctrine to which the results of experiments seem to point; but, as it has been justly remarked by Longet, the effects of disease are only partly comparable to those of experiment; since in a large proportion of chronic cases of the former, the change consists in the formation of a new product, such as a tubercular or cancerous deposit, or a cyst of some kind, the gradual development of which is quite consistent with the continued functional activity of the organ, as we see by parallel phenomena elsewhere; whilst in those instances in which hemorrhage occurs, this usually occasions either complete apoplexy or local paralysis, by its effects upon other organs. Still, several cases of chronic disease of the Cerebellum have been observed, in which *unsteadiness of gait,* without paralysis, or only giving place to paralysis at last on the occurrence of hemorrhage, was a very marked symptom;† and these afford a strong confirmation of the doctrine based on the experimental researches already referred-to. In a few cases in which both lobes of the Cerebellum have been seriously affected, the tendency to retrograde movement has been observed; and instances are also on record, of the occurrence of rotatory movement, which has been found to be connected with lesion of the Crus Cerebelli on the same side.‡ So far as they can be relied on, therefore, the results of the three methods of investigation bear a very close correspondence; and it can scarcely be doubted that they afford us a near approximation to truth.

766. It must not be allowed to pass unnoticed, that some Physiologists (as Foville, Pinel-Grandchamp, and Dugès) have regarded the Cerebellum as the centre of common Sensation; chiefly on the ground of its connection with the posterior columns of the Spinal Cord, and of the manifestations of pain which are called forth by touching the Restiform columns. Although these facts may lead us to admit that the Cerebellum is connected with the sensorial centres, and even that it is itself *a* seat of sensibility, yet it is impossible to regard it as the exclusive seat

* See his "Clinique Medicale," 2ème edit. tom. v. p. 735.

† Two such cases are recorded by Mr. Dunn in the "Med.-Chir. Trans.," vol. xxxii., and another by Dr. Cowan in the "Prov. Med. and Surg. Journ.," April 16, 1845; and the Author has been made acquainted with several others, by gentlemen under whose cognizance they have fallen.

‡ A collection of such cases has been made by Dr. Paget, in his paper on 'Morbid Rhythmical Movements,' in the "Edinb. Med. and Surg. Journal," 1847, vol. lxvii.—A case fell within the Author's knowledge a few years ago, in which a state of this kind, that lasted for some hours, appeared to depend upon an attack of indigestion; the symptoms being completely relieved by vomiting, and no further indication of encephalic disorder manifesting itself.

of sensibility, consistently with the facts with which experiment and pathological observation supply us; since neither the complete removal of this organ by operation, nor its complete destruction by disease,* have been found to involve any loss of the ordinary sensorial powers.—There would seem much more probability in the idea that it is the special seat of the 'muscular sense,' which has so important a share in the guidance of the co-ordinated movements; and this notion derives confirmation from the marked structural connection which exists between the Cerebellum and the Optic Ganglia (corpora quadrigemina), the purpose of which may be not unfairly surmised to be, to communicate the guidance of the *visual* sense to the organ by which the co-ordination of motions is effected, in the same manner as the impressions appertaining to the muscular sense are transmitted upwards by the Restiform columns. The chief objection to such a view would seem to lie in the strong similarity between the 'muscular' sense and 'common' or 'tactile' sensation, which makes it difficult to conceive that they should have different seats in the *Sensorium commune.* But this difficulty is diminished if not removed by the reflection, that the Restiform columns appear to have the same endowments as the remainder of the Sensory tract derived from the posterior columns of the Spinal Cord; and that no explanation can be given of their extreme sensitiveness to impressions (as shown by experiment), unless it be admitted that the organ in which they terminate is itself a centre of a form of sensation closely allied to that of the common or tactile kind. Possibly, however, the true termination of these fibres is in the 'corpus dentatum' of the Crura Cerebelli; and the Cerebellum may only react upon impressions thence transmitted to it, without being itself the instrument of communicating such impressions to the consciousness.

767. We have now to examine, however, another doctrine regarding the functions of the Cerebellum, which was first propounded by Gall, and which is supported by the Phrenological school of physiologists. This doctrine, that the Cerebellum is the organ of the sexual instinct, is not altogether incompatible with the other; and by some it has been held in combination with it. The greater number of Phrenologists, however, regard this instinct as the *exclusive* function of the Cerebellum; and assert that they can judge of its intensity, by the degree of development of the organ. We shall now examine the evidence in support of this position, afforded by the three methods of inquiry which have been already indicated. In the first place it may be remarked, that the sexual propensity is very closely connected with various emotional states of mind to which "organs" are assigned by Phrenologists, and of which the Cerebrum is universally admitted to be the seat; such for instance as "love of offspring," "adhesiveness," and in the lower animals more particularly with "combativeness;" and in Man it has a continual operation upon the reasoning faculties and the Will. Yet the anatomical connections of the Cerebellum are peculiarly unfavourable to any such influence; these being, as we have seen, rather with the lower than with the higher portion of the Cerebro-spinal axis.—Again, the results of fair observation as to the comparative size of the Cerebellum in different animals, can

* See the well-known case recorded by Combetti, in the "Revue Médicale," tom. ii. p. 57.

scarcely be regarded as otherwise than very unfavourable to the doctrine in question. In the greater number of Fishes, it is well known that no sexual congress takes place; the seminal fluid being merely effused, like any other excretion, into the surrounding water; and being thus brought into only accidental contact with the ova, of which a large proportion are never fertilized. But there are certain Fishes, as the Sharks, Rays, and Eels, in which copulation takes place after the ordinary method. Now on contrasting these groups, we find no corresponding difference in the size of the Cerebellum. It is true that this organ is of large size in the Sharks; but it is smaller in the Rays, and almost rudimentary in the Eels; in this respect bearing a precise correspondence with the variety and complexity of their movements. Further, in many ordinary Fishes, which do *not* copulate, such as the Cod, the Cerebellum is not only larger, but more complex in structure, than it is in the generality of Reptiles, in which the sexual instinct is commonly strong; the whole spinal system of the Frog possessing, at the season of reproduction, an extraordinary degree of excitability, which is evidently destined to aid in the performance of the function. Again, on comparing the Gallinaceous Birds, which are polygamous, with the Raptorial and Insessorial tribes which live in pairs, we find that the former, instead of having a larger Cerebellum, have one of inferior size. Further, on looking at the Mammalia, the same disproportion may be noticed. A friend who kept some Kangaroos in his garden, informed the Author that they were the most salacious animals he ever saw; yet their Cerebellum is one of the smallest to be found in the class. Every one knows, again, the salacity of Monkeys; there are many which are excited to violent demonstrations by the sight even of a human female; and there are few which do not practise masturbation, when kept in solitary confinement; yet in them the Cerebellum is much smaller than in Man, in whom the sexual impulse is much less violent. It has been supposed that the large size of the organ in Man is connected with his *constant* possession of the appetite, which is only *occasional* in others; but this does not hold good, since among domestic animals there are many which are ready to breed throughout the year, Cats and Rabbits for instance, and in these we do not find any peculiar difference in the size of the Cerebellum.*

768. It is asserted, however, that the results of observation in Man lead to a positive conclusion, that the size of the Cerebellum is a measure of the intensity of the sexual instinct in the individual. This assertion has been met by the counter-statement of others, that no such relation exists. It is unfortunate that here, as in many other instances, each party has registered the observations favourable to its own views, rather than those of an opposite character; so that until some additional evidence of a less partial nature shall have been collected, we must consider the question as *sub judice.* It may be safely affirmed, however, that no evidence upon the affirmative side of this proposition has yet been adduced, which can be in the least degree satisfactory to the mind of any Anatomist who is competent to judge of its value. For nearly all the observations which have been paraded by Phrenologists in support of Gall's

* For a fuller examination of the indications afforded by Comparative Anatomy in regard to this question, see the "Brit. and For. Medical Review," Oct., 1846, pp. 534.

doctrine, have been based, *not* upon the actual *determination* of the size or weight of the Cerebellum in different individuals, but upon the *estimation* of its proportional development from the external conformation of the skull. Now any one who has even cursorily examined those principal types of cranial conformation, which are characteristic of some of the chief subdivisions of the Human species, must perceive that there is a no less characteristic difference between these different types in the occipital, than there is in the frontal region. For whilst the occipital projection is much *greater* in the 'prognathous' skull than it is in the 'elliptical,' it is as much *less* in the 'pyramidal;' and thus while the first would be considered, according to phrenological rules, to hold a much larger Cerebellum, this organ in the latter would be regarded as necessarily very small. Now there is not only as much evidence of a strong development of the sexual propensity, in the characters and habits of the pyramidal-skulled Asiatics, as there is in regard to the elliptical-skulled Europeans, or the prognathous Negroes; but there is also anatomical evidence to show that *the size of the Cerebellum in the different races bears no relation whatever to the degree of projection of the occiput;* for the plane of this organ, being somewhat oblique in the elliptical skull, is horizontal in the prognathous, and nearly vertical in the pyramidal, while the size and anatomical relations of the organ are not in the least degree affected by this difference in its position.*—Hence it may be safely affirmed, that no evidence with regard to the relation asserted to exist between the size of the Cerebellum and the intensity of the Sexual propensity, has any value, save that which is drawn from the positive determination of the former by measure or weight.

769. Among the arguments adduced by Gall and his followers in proof of the connection between the Cerebellum and the sexual instinct, is one which would deserve great attention, if the facts stated could be relied-on. It has been asserted, over and over again, that the Cerebellum, in animals which have been castrated when young, is much smaller than in those which have retained their virility,—being, in fact, *atrophied* from want of power to act. Now it is unfortunate that vague assertion, founded on estimates formed by the eye from the cranium alone, is all on which this position rests; and it will be presently shown how very liable to error such an estimate must be. The following is the result of a series of observations on this subject, suggested by M. Leuret,† and carried into effect by M. Lassaigne:—The *weight* of the Cerebellum, both absolutely, and as compared with that of the Cerebrum, was adopted as the standard of comparison. This was ascertained in ten Stallions, of the ages of from nine to seventeen years; in twelve Mares, aged from seven to sixteen years; and in twenty-one Geldings, aged from seven to seventeen years. The average weight of the Cerebrum in the *Stallions* was 433 grammes; the greatest being 485 gr., and the least (which was in a horse of ten years old) being 350 gr. The average weight of the Cerebellum was 61 gr.; the greatest being 65 gr., and the least 56 gr. The average proportion borne by the weight of the Cerebellum to that of the Cerebrum, was, therefore, 1 to 7·07; the highest (resulting from a very small Cere-

* The Author's statements on this point are based on the very decided assertions of his friend Prof. Retzius of Stockholm, who has paid special attention to this inquiry.

† "Anat. Comp. du Système Nerveux," tom. i. p. 427.

brum) being 1 to 6·25; and the lowest (resulting from an unusually large Cerebrum) being 1 to 7·46. Throughout it might be observed, that the variation in the size of the Cerebellum was much less than in that of the Cerebrum.—In the twelve *Mares*, the average weight of the Cerebrum was 402 gr.; the highest being 432 gr., and the lowest 363 gr. That of the Cerebellum was 61 gr.; the highest being 66 gr. (which was in the individual with the smallest Cerebrum), and the lowest 58 gr. The average proportion of the weight of the Cerebellum to that of the Cerebrum was 1 to 6·59; the highest being 1 to 5·09, and the lowest 1 to 7. The proportion was, therefore, considerably higher in the perfect female, than in the perfect male.—In the twenty-one *Geldings*, the average weight of the Cerebrum was 419 gr.; the highest being 566 gr., and the lowest 346 gr. The average of the Cerebellum was 70 gr.; the highest being 76 gr., and the lowest 64 gr. The average proportion was, therefore, 1 to 5·97; the highest being 1 to 5·16, and the lowest 1 to 7·44. It is curious, that this last was in the individual which had the largest Cerebellum of the whole; but the proportional weight of the Cerebrum was still greater.—Bringing together the results of these observations, they are found to be quite opposed to the statement of Gall. The weight of the Cerebrum, reckoning the Cerebellum as 1, is thus expressed in each of the foregoing descriptions of animals :—

| | *Average.* | *Highest.* | *Lowest.* |
|---|---|---|---|
| Stallions . . . | 7·07 | 7·46 | 6·25 |
| Mares . . . | 6·59 | 7·00 | 5·09 |
| Geldings . . . | 5·97 | 7·44 | 5·16 |

The average *proportional* size of the Cerebellum in Geldings, therefore, is so far from being *less* than that which it bears in entire Horses and Mares, that it is positively greater; and this depends not only on diminution in the relative size of the Cerebrum, but on its own larger dimension, as the following comparison of *absolute* weights will show :—

| | *Average.* | *Highest.* | *Lowest.* |
|---|---|---|---|
| Stallions . . . | 61 | 65 | 56 |
| Mares . . . | 61 | 66 | 58 |
| Geldings . . . | 70 | 76 | 64 |

The difference is so remarkable, and appears, from examination of the individual results, to be so constant, that it cannot be attributed to any accidental circumstance, arising out of the small number of animals experimented on. The average weight of the Cerebellum in the ten Stallions and twelve Mares, is seen to be the same, and the extremes differ but little in the two; whilst the average in the Geldings is more than one-seventh higher, and the *lowest* is considerably above the *average* of the preceding, while the highest far exceeds the highest among the entire Horses. It is curious that Gall would have been much nearer the truth, if he had said that the dimensions of the *Cerebrum* are usually reduced by castration; for it appears from the following table that such is really the case :—

| | *Average.* | *Greatest.* | *Least.* |
|---|---|---|---|
| Stallions . . . | 433 | 485 | 350 |
| Mares . . . | 402 | 432 | 336 |
| Geldings . . . | 419 | 566 | 346 |

The weight of the largest Cerebrum of the Gelding is far above the highest of the Stallions; but it seems to be an extraordinary case, as in no other was the weight above 490 gr. If this one be excluded, the *average* will be reduced still further, being then about 412; this may be seen, by looking over the whole table, to give a very fair idea of the usual weight in these animals, which is therefore *less*, by about one-twentieth, than the average in the Stallions.—The increased size of the Cerebellum in Geldings may perhaps be accounted-for, by remembering that this class of horses is solely employed for its muscular power, and that the constant exercise of the organ is not unlikely to develope its size; whilst Stallions, being kept especially for the purpose of propagation, are much less applied to occupations which call forth their motor faculties.

770. It is asserted, however, by the followers of Gall, that very strong evidence of the truth of his doctrine is afforded by Pathological phenomena: excitement of the genital organs, manifesting itself in priapism, turgescence of the testes, and seminal emissions, being an ordinary concomitant of some forms of apoplexy in which the Cerebellum is affected; whilst in other cases of disease or injury involving extensive destruction of the substance of the organ, there has been a complete abatement of sexual desire. The proportion of recorded cases of disease of the Cerebellum, however, in which any affection of the genital organs has been noticed, is extremely small; for out of 178 cases, which have been collected by Burdach,* only 10, or scarcely more than 1 in 18, presented any symptoms that tended to indicate a functional relation between the Cerebellum and the Genital organs. The same physiologist affirms that similar affections present themselves when the Cerebrum is the seat of the lesion; and there seems a strong probability that it is solely to the connection of these organs with the Spinal Cord, that such affections of the genital apparatus are due. For erection of the penis has been noticed in a far larger proportion of cases in which the Spinal Cord itself has been the seat of the lesion; thus in 15 cases in which the cervical portion of the Cord was affected, erection of the penis was observed in 8; and in 13 cases of lesion of the dorso-lumbar portion of the cord, erection of the penis took place in 3.† It is well known that erection of the penis and emissio seminis are not infrequent phenomena of death by hanging; and this fact accords fully as well with the idea that the affection of the sexual organs is consequent upon lesion of the Cranio-Spinal axis, as with the doctrine that it is due to disordered function of the Cerebellum.—It has been suggested by Serres,‡ who collected 7 cases in which excitement of the genital organs was coincident with apoplexy of the median lobe of the Cerebellum, that whilst the lateral lobes or hemispheres may be connected with the locomotive function, the median lobe may be the organ of the sexual instinct. Several cases have been recorded, in which some such relation appeared to be indicated; and the Author has been made acquainted with at least six,§

* "Von Baue und Leben des Gehirns," (Leipzig, 1819–26), band iii.

† See the "Traité des Maladies de la Moëlle Epinière" of M. Ollivier (d'Angers), 3ème édit., tom. iii. p. 316.

‡ "Anatomie Comparée du Cerveau," tom. ii. pp. 601, 717.

§ Four such cases have come under the notice of his friend Dr. Simpson of York.

in which an extraordinary salacity developed itself at an advanced period of life, whilst concurrently with this, or following upon it, there was that kind of unsteadiness of gait which may be held to indicate chronic disease of the Cerebellum; and in one of these cases, of which the history and post-mortem appearances have been carefully recorded by Mr. Dunn,* there was strong evidence that the excitement of the sexual propensity was coincident with the irritative stage of incipient disease in the central lobe of the Cerebellum, and that the abatement of the propensity was in like manner coincident with the subsequent destruction of its substance; whilst the advance of the disease into the lateral lobes was marked by impairment of the power of co-ordination of movement. But with regard to all such cases, and others that may be ranked in the same category,† the objection of Pétrequin‡ holds good, that when disease or injury affects the median lobe of the Cerebellum, the Medulla Oblongata is almost certain to be implicated in it; so that, as the evidence already referred-to clearly indicates the existence of a special relation between the genital organs and the upper part of the Spinal Axis, no positive proof is afforded by them that any portion of the Cerebellum has any special connection with the generative function.

771. The Author is far from denying *in toto*, that any peculiar connection exists between the Cerebellum and the Genital system; but if the evidence at present adduced in support of the Phrenological position be held sufficient to establish it, in defiance of so many opposing considerations, we must bid adieu to all safe reasoning in Physiology. The weight of testimony appears to him to be quite decided, in regard to the connection of the Cerebellum with the regulation of the motor function; and as an additional argument in favour of this view, it may be stated, that the lobes of the Human Cerebellum undergo their most rapid development during the first few years of life, when a large number of complex voluntary movements are being learned by experience, and are being associated by means of the muscular sensations accompanying them; whilst in those animals which have, immediately after birth, the power of regulating their voluntary movements for definite objects, with the greatest precision, the Cerebellum is more fully developed at the time of birth. In both instances it is well formed and in active operation (so far as can be judged of by the amount of circulation through it), long before the sexual instinct manifests itself in any perceptible degree.—But neither doctrine need be maintained altogether to the exclusion of the other; and there are many among the Phrenologists of the present day, who hold with Serres that whilst the hemispheres of the Cerebellum possess the endowments now

* "Medico-Chirurgical Transactions," vol. xxxii.

† Thus, a case has been communicated to the Author by Mr. Turley of Worcester, in which the sexual desire, which had been always strong through life, but which had been controlled within the limits of decency, manifested itself, during a period of some months preceding death, in a most extraordinary degree; on *post mortem* examination, a tumour was found on the Pons Varolii.—And he has been informed of another case by Dr. Evanson (formerly of Dublin), in which a young officer on the eve of marriage, having received a blow on the occiput by a fall from his horse, became impotent, without any other disorder of his bodily or mental powers; and in the distress consequent upon this discovery, committed suicide on the morning fixed for his wedding.

‡ 'Sur quelques points de la Physiologie du Cervelet et de la Moëlle Epinière,' in "Gaz. Médicale," 1836, tom. iv. p. 546.

generally assigned to them by Physiologists, the central lobe is connected with the Genital function. It has been shown by Dr. N. S. Davis,* however, that there is no perceptible difference in the dimensions of this central lobe, any more than in those of the hemispheres, between Bulls and Oxen; and no proof has yet been offered, save that afforded by the pathological evidence just referred-to, that any such endowment is possessed by it. That in some way or other, however, either the central portion of the Cerebellum, or some part of the Medulla Oblongata, has a special connection with the Generative function, appears to the Author to be indicated with tolerable clearness by several of the pathological phenomena already cited. The circumstance, too, of which he has frequently been assured, that great application to gymnastic exercises diminishes for a time the sexual vigour, and even totally suspends desire, seems worthy of consideration in reference to such a view; for if the Cerebellum be really connected with both kinds of function, it does not seem unreasonable that the excessive employment of it upon one should diminish its energy in regard to the other.—An analysis of the nature of the Sexual propensity, however, suggests the conclusion that we are not to look in this part of the Encephalon for anything else than a seat of the sexual *sensation;* the character of which seems to be sufficiently different from that of mere *tactile* sensation, to require a distinct ganglionic centre. Such a centre would be likely to be placed in the line of the other sensory ganglia, and in close connection with them.

772. As in the case of other sensations, the sexual, when moderately excited, may give rise to ideas, emotions, and desires, of which the Cerebrum is the seat; and these may react on the muscular system through the Intelligence and Will. But when inordinately excited, or when not kept in restraint by the Will, the sexual sensations will at once call into play respondent movements, which are then to be regarded as purely automatic; this is the case in Nymphomania and Satyriasis in the Human subject; and it is probably also the ordinary mode of operation of this sense, in such of the lower animals as have not psychical power enough to form a conception of an absent object of gratification, and cannot, therefore, be said to have sexual *desires.* Thus, like other sensations, it may act either *intelligentially* or *automatically;* giving rise to *ideas,* by transmission to the Cerebrum, which ideas, associated with pleasurable feelings, originate *desires,* which stimulate the reasoning powers to devise means for their gratification, and excite the will to the necessary actions; or, by its immediate action upon the motor apparatus, producing respondent *movements.*—Of this double *modus operandi* we seem to have sufficient evidence. For among many of the lower tribes of animals, at the time when the generative organs are in a state of functional activity, the presence of an individual of the opposite sex, indicated by the sight, smell, hearing, or touch, immediately excites the whole train of instinctive actions concerned in the reproductive operation; whilst we have no evidence in them of any voluntary exertion, resulting from the existence of a desire entertained in the absence of the object, and intended for the gratification of that desire. In Man, on the other hand, the principal operation of the sexual sensations is in awakening desires and affections,

* "Transactions of American Medical Association," vol. iii. p. 415.

which serve as excitements to the intelligence and as motives to the will; and it is only, under ordinary circumstances, when the two sexes have been thus brought into close relation, that the direct reaction of the sexual sensation manifests itself in automatic movements. In cases, however, in which this sensation is excited in unusual strength, it may completely overmaster all motives to the repression of the propensity, and may even entirely remove the actions from the control of the will; and a state of a very similar kind exists in many idiots, in whom the sexual propensity exerts a dominant power, not because it is in itself peculiarly strong, but because, the intelligence being undeveloped, it acts without control or direction from the will.

### 5. *The Cerebrum, and its Functions.*

773. We come, in the last place, to consider the functions of that portion of the Nervous Centres, which is evidently, in Man, the predominant organ of his whole system; being not merely the instrument of his reasoning faculties, but also possessing a direct or indirect control over nearly all the actions of his corporeal frame, save those purely vegetative processes, which are most completely isolated from his animal powers. We should be in great danger, however, of coming to an erroneous conclusion as to the real character of the Cerebrum and of its operations, if we confined ourselves to the study of the Human organism; and the history of Physiological science shows, that every advance of knowledge respecting its functions, has tended to *limit* them, whilst at the same time rendering them *more precise.* Thus the Brain (this term, in the older Anatomy, being chiefly appropriated to the Cerebrum) was accounted, not merely the centre of all motion and sensation, but also the source of all vitality; the different processes of nutrition, secretion, &c., being maintained, it was supposed, by a constant supply of "animal spirits," propagated from the brain, along the nerves, to each individual part. The more modern doctrine, that the Sympathetic System has for its special function to supply the nervous influence requisite for the maintenance of the functions of Organic life, was the first step in the process of limitation; still the Brain was regarded as the centre of all the Animal functions; and no other part was admitted to possess any power independently of it. By experiments and pathological observations, however, the powers of the Spinal Cord as an independent centre of action were next established; and it was thus shown, that there is a large class of motions, in which the Brain has no concern, and that the removal of the Cerebral hemispheres is not incompatible (even among the higher Vertebrata) with the prolonged maintenance of a sort of inert and scarcely conscious life. Still, it has been usually maintained, and with great show of reason, that the Cerebrum is the instrument of all *psychical* operations, and the originator of *all* the movements which could not be assigned to the reflex action of the Spinal Cord. An attempt has been made, however, in the preceding pages, to show that this view is not correct; and that there is a class of actions, neither excito-motor nor voluntary, but directly consequent upon Sensations, and constituting (with the excito-motor) the truly *instinctive* actions, which may be justly assigned to certain ganglionic centres, not less independent of the Cerebrum than is

the Spinal Cord itself. It has been further advanced, that the Cerebrum must be considered in the light of an organ *superadded* for a particular purpose or set of purposes, and not as one which is essential to life; that it has no representative among the Invertebrata (except in a few of the highest forms, which evidently present a transition towards the Vertebrated series); and that, at its first introduction, in the class of Fishes, it evidently performs a subordinate part in the general actions of the Nervous System. Hence, whatever be the function, or set of functions, we assign to the Cerebrum, we must keep in view the *special* character of the organ; and must never lose sight of the fact, that its predominance in Man does not deprive other parts of their independent powers, although it may keep the exercise of those powers in check, and may considerably modify their manifestations.

774. Before proceeding to inquire into the Physiology of the Cerebrum, we may advantageously take notice of some of the leading features of its structure. — In the first place, it forms an exception to the general plan on which the elements of ganglionic centres are arranged; in having its vesicular substance on the *exterior*, instead of in the *central* part of the mass. The purpose of this is probably to allow the vesicular matter to be disposed in such a manner, as to present a very large *surface*, instead of being aggregated together in a more compact mass; and by this means to admit, on the one side, the more ready access of the blood-vessels which are so essential to the functional operations of this tissue, as well as the more ready communication, on the other, with the vast number of fibres by which its influence is to be propagated. There is no reason whatever to believe, that the relative functions of the vesicular and fibrous substances are in the least altered by this change in their relative position; indeed, the results of observation upon the phenomena of disordered Cerebral action are such, as to afford decided confirmation to the doctrine already propounded, that the action of the vesicular matter constitutes the source of nervous power, whilst the fibrous structure has for its office to conduct the influence generated in it towards the points at which this is to operate. The purpose of this arrangement is further evidenced by the fact, that, in all the higher forms of Cerebral structure, we find a provision for a still greater extension of the surface at which the vesicular matter and the blood-vessels may come into relation; this being effected, by the plication of the layer of vesicular matter into 'convolutions,' into the sulci between which, the highly vascular membrane known as the 'pia mater' dips down, sending multitudes of small vessels from its inner surface into the substance it invests.—In the fibrous or medullary substance of which the great mass of the Cerebrum is composed, three principal sets of fibres may be distinguished. These are,—*first*, the radiating fibres, which connect the vesicular matter of the cortical substance of the Hemispheres with the Thalami Optici, and which, if our view of the function of the latter be correct, may be regarded as *ascending* or *sensory*;—*second*, the radiating fibres, which connect the vesicular matter of the cortical substance of the Hemispheres with the Corpora Striata, and which, on similar grounds, may be regarded as *descending* or *motor*;—and *third*, the Commissural fibres, which establish the connection between the opposite Hemispheres, and between the different parts of the vesicular substance of the same side, especially between

that disposed on the surface of each hemisphere, and those isolated patches which are found in its interior. It is on the very large proportion which the Commissural fibres bear to the rest, that the bulk of the Cerebrum of Man and of the higher animals seems chiefly to depend; and it is easy to conceive, that this condition has an important relation with the operations of the Mind, whatever be our view of the relative functions of different parts of the Cerebrum. It appears from the late researches of M. Baillarger, that the *surface* and the *bulk* of the cerebral hemispheres are so far from bearing any constant proportion to each other, in different animals, that, notwithstanding the depth of the convolutions in the Human Cerebrum, its bulk is $2\frac{1}{2}$ times as great in proportion to its surface, as it is in the Rabbit, the surface of whose Cerebrum is smooth. The entire surface of the Human Cerebrum, when the convolutions are unfolded, is estimated by him at about 670 square inches.*

775. With regard to the *Radiating* fibres, which connect the Corpora Striata and Thalami Optici with the vesicular surface of the Cerebral hemispheres, no positive proof has yet been obtained of their direct continuity with those which enter into the composition of the nerves proceeding from the Spinal Cord and Medulla Oblongata; and we have seen (§ 753) that there are certain phenomena, which are far better explained on the idea, that these radiating fibres are of a *commissural* nature only, serving to connect the vesicular matter of the Cerebrum with that of the higher portions of the *Cranio-Spinal Axis*, through which alone they are brought into relation with the central terminations of the afferent nerves, and with the origins of the motor. On this view, the Cerebrum would receive all its sensory impressions, by the commissural fibres that connect it with the ganglia, which are the real centres of these nerves; whilst it would call the motor trunks into action, by exciting, through another set of commissural fibres, the vesicular matter of the ganglionic centres from which they pass forth. The idea that there is no direct continuity between the radiating fibres of the Cerebrum and the fibres of the nerve-trunks, derives support from the fact, in which the results of all experiments agree, that no irritation of the former produces either sensation or motion. These results are borne out by pathological observations in Man; for it has been frequently remarked, when it has been necessary to separate protruded portions of the Brain from the remainder, that this has given rise to no sensation, even in cases in which the mind has been perfectly clear at the time, nor has any convulsive action been produced. Such evidence, however, is by no means conclusive on the point; since the same is true of the Thalami Optici and Corpora Striata, in which there is more decided evidence of the absolute continuity of fibres from the nerve-roots to the vesicular substance of these parts respectively.

776. The *Commissural* fibres constitute two principal groups, the

* The inference drawn by M. Baillarger from the facts he has collected,—namely, that the proportional surface of vesicular matter in different animals, whether considered absolutely, or relatively to the volume of the Cerebrum, has no correspondence with their intellectual capability,—is far too sweeping an assumption; since, as above shown, the increase in the commissural fibres, causing an augmentation of the bulk of the Cerebrum, may be alike the cause of increased intelligence and of a diminished proportional amount of vesicular matter; though the latter still remains as the original source of power.

*transverse*, and the *longitudinal;* the former connecting the two Hemispheres with each other; the latter uniting the different parts of the same Hemisphere.—Of the transverse commissures, the *Corpus Callosum* is the most important. This consists of a mass of fibres very closely interlaced together; which may be traced into the substance of the hemispheres on each side, particularly at their lower part, where their connections are the closest with the Thalami Optici and Corpora Striata. It is difficult, if not impossible, to trace its fibres any further; but there can be little doubt that they radiate, with the fibres proceeding from the bodies just named, to different parts of the cortical substance of the Hemispheres. This commissure is altogether wanting in Fish, Reptiles, and Birds; and it is partially or completely wanting in those Mammals, whose Cerebrum is formed upon the least complex plan—the Rodents and Marsupials. The *Anterior* commissure particularly unites the Corpora Striata of the two sides: but many of its fibres pass through those organs, and radiate towards the convolutions of the Hemispheres, especially those of the middle lobe. This commissure is particularly large in those Marsupials, in which the Corpus Callosum is deficient. The *Posterior* commissure is a band of fibres which connects together the Thalami Optici; crossing over from the posterior extremity of one to that of the other. Besides these, there are other groups of fibres, which appear to have similar commissural functions, but which are intermingled with vesicular substance. Such are the *soft* commissure, which also extends between the Thalami; the *Pons Tarini*, which extends between the Crura Cerebri; and the *Tuber Cinereum*, which seems to unite the optic tracts with the thalami, the corpus callosum, the fornix, &c., and to be a common point of meeting for several distinct groups of fibres.—Of the *longitudinal* commissures, some lie above, and others below, the Corpus Callosum. Upon the transverse fibres of that body, there is a longitudinal tract on each side of the median line, which serves to connect the convolutions of the anterior and posterior Cerebral lobes. Above this, again, is the *Superior longitudinal* commissure, which is formed by the fibrous matter of the greater convolutions nearest the median plane on the upper surface of the Cerebrum, and which connects the convolutions of the anterior and middle lobes with those of the posterior. Beneath the Corpus Callosum, we find the most extensive of all the longitudinal commissures, the *Fornix*. This is connected in front with the Thalami Optici, the Corpora Mammillaria, the Tuber Cinereum, &c.; and behind, it spreads its fibres over the Hippocampi (major and minor), which are nothing else than peculiar convolutions that project into the posterior and descending cornua of the lateral ventricles. The fourth longitudinal commissure is the *Tænia semicircularis*, which forms part of the same system of fibres with the fornix; connecting the corpus mammillare and thalamus opticus of each side with the middle lobe of the cerebral hemisphere. If, as Dr. Todd has remarked,* we could take away the corpus callosum, the grey matter of the internal convolution, and the ventricular prominence of the optic thalami, then all these commissures would fall together, and would become united in the same series of longitudinal fibres.—Experiment does not throw any light upon the particular functions of the Corpus Cal-

* "Anatomy of the Brain, Spinal Cord," &c., p. 234.

osum and other Commissures; since they can scarcely be divided without severe general injury. It would appear, however, that the partial or entire absence of these parts, reducing the Cerebrum (in this respect at least) to the level of that of the Marsupial Quadruped, or of the Bird, is by no means an unfrequent cause of deficient intellectual power.*

777. The weight of the entire Encephalon in the adult Male usually ranges between 40 and 60 oz., the average being about 50 oz.; and in the Female, from 36 to 50 oz., the average being about 45 oz. The maximum of the healthy brain seems to be about 64 oz., and the minimum about 31 oz. But in cases of idiocy, the amount is sometimes much below this; as low a weight as 20 ounces having been recorded.—It appears, from the recent investigations of M. Bourgery, that the relative sizes of the different component elements of the Human Encephalon are somewhat as follows. Dividing the whole into 204 parts, the weight of the Cerebrum will be represented by about 170 of those parts, that of the Cerebellum by 21, and that of the Medulla Oblongata with the Optic Thalami and Corpora Striata at 13. The weight of the Spinal Cord would be, on the same scale, 7 parts. Hence the Cerebral Hemispheres of Man include an amount of nervous matter, which is *four* times that of all the rest of the Cranio-Spinal mass, more than *eight* times that of the Cerebellum, *thirteen* times that of the Medulla Oblongata, &c., and *twenty-four* times that of the Spinal Cord.—The average weight of the whole Encephalon, in proportion to that of the body, in Man, taking the average of a great number of observations, is about 1 to 36. This is a much larger proportion than that which obtains in most other animals; thus the average of Mammalia is stated by M. Leuret to be 1 to 186, that of Birds 1 to 212, that of Reptiles 1 to 1321, and that of Fishes 1 to 5668. It is interesting to remark, in reference to these estimates, that the Ence-

* The following case of deficient commissures, recorded by Mr. Paget ("Medico-Chirurg. Transactions," vol. xxiv.), is of much interest. The middle portion of the Fornix, and the whole of the Septum Lucidum, were absent; and in place of the Corpus Callosum, there was only a thin fasciculated layer of fibrous matter, 1·4 inch in length, but of which the fibres extended to all the parts of the brain into which the fibres of the healthy corpus callosum can be traced. The Middle commissure was very large; and the lateral parts of the Fornix, with the rest of the Brain, were quite healthy. The patient was a servant-girl, who died of pericarditis. She had displayed during her life, nothing very remarkable in her mental condition, beyond a peculiar *want of forethought* and *power of judging of the probable event of things*. Her memory was good; and she possessed as much ordinary knowledge as is commonly acquired by persons in her rank of life. She was of good moral character, trustworthy, and fully competent to all the duties of her station, though somewhat heedless; her temper was good, and disposition cheerful.—The mental deficiencies in most of the few other cases of which the details have been recorded, seem to have been of the same order; and this is exactly what might have been anticipated; since the deprivation of these parts takes away that, which is most characteristic of the Cerebrum of Man and of the higher Mammalia; *their* intellectual operations being peculiarly distinguished by that *application of past experience to the prediction of the future*, which constitutes one of the highest efforts of Intelligence.—Another case has been since put on record by Mr. Mitchell Henry (Op. cit., vol. xxxi.), in which the anterior portion of the Corpus Callosum was deficient, together with the middle and anterior portion of the Fornix, and the whole of the Septum Lucidum. There was in this case, also, a marked intellectual deficiency, but apparently of a different character from that which showed itself in the preceding case; for instead of vivacity and habitual rapidity of action, there was here a disproportionate degree of slowness in action, amounting almost to stupidity. The difference in the two cases, however, is perhaps to be set down rather to the account of general temperament; since in both of them there seems to have been a deficiency in the power of carrying on a continuous train of thought.

phalic prolongation of the Medulla Oblongata in Man (being about one-sixteenth of the weight of the whole Encephalon) is *alone* more than twice as heavy in proportion to his body, as the *entire* Encephalon of Reptiles, and ten times as heavy as that of Fish.—But there are some animals in which the weight of the Encephalon bears a higher proportion to that of the body than it does in Man; thus in the Blue-headed Tit, the proportion is as 1 to 12, in the Goldfinch as 1 to 24, and in the Field-Mouse as 1 to 31. It does not hence follow, however, that the *Cerebrum* is larger in proportion; in fact, it is probably not nearly so large; for in Birds and Rodent Mammals, the Sensory Ganglia form a very considerable proportion of the entire Encephalon. The importance of distinguishing between the several parts of this mass, which are marked-out as distinct, alike by their structure and connections, as by the history of their development, has not been by any means sufficiently attended to.

778. The Encephalon altogether receives a supply of Blood, the amount of which is very remarkable, when its comparative bulk is considered; the proportion which goes to it being, according to the estimate of Haller, as much as one-fifth of the whole. The manner in which this blood is conveyed to the brain, and the conditions of its distribution, offer some peculiarities worthy of notice. The two Vertebral and two Carotid arteries, by which the blood enters the cavity of the cranium, have a more free communication by anastomosis, than any similar set of arteries elsewhere; and this is obviously destined to prevent an obstruction in one trunk from interrupting the supply of blood to the parts through which its branches are chiefly distributed,—the cessation of the circulation through the nervous matter being immediately productive (as formerly shown, § 355) of suspension of its functional activity.—Not only must there be a sufficient supply of blood, but it must make a regulated pressure on the walls of the vessels. Now the Encephalon is differently circumstanced from other vascular organs, in being enclosed within an unyielding bony case (§ 533); and we find a special provision for equalizing the bulk of the contents of this cavity, and for counterbalancing the results of differences in the functional activity of the brain and in its supply of blood, in the existence of a fluid which is found beneath the arachnoid, both on the surface of the brain and spinal cord, and in the ventricles of the former. The amount of this 'cerebro-spinal fluid' seems to average about two ounces; but in cases of atrophy of the brain, as much as twelve ounces of fluid may sometimes be obtained from the cranio-spinal cavity; whilst in all instances in which the bulk of the brain has undergone an increase, whether from the production of additional nervous tissue, or from undue turgescence of the vessels, there is either a diminution or a total absence of this fluid. It appears from the experiments of Magendie (to whom our knowledge of the importance of this fluid is chiefly due), that its withdrawal in living animals causes great disturbance of the cerebral functions, probably by allowing undue distension of the blood-vessels; it is, however, capable of being very rapidly regenerated; and its reproduction restores the nervous centres to their natural state.—As the 'cerebro-spinal fluid' can readily find its way from the subarachnoid spaces of the *cranial* cavity into those of the *spinal*, and as it is no less readily absorbed than reproduced, it evidently serves as an equalizer of the amount of pressure within the cranial cavity; admitting the dis-

tension or contraction of the vessels to take place, within certain limits, without any considerable change in the degree of compression to which the nervous matter is subjected. That this uniformity is of the greatest importance to the functional exercise of the brain, is evident from a few well-known facts. If an aperture be made in the skull, and the protruding portion of the brain be subjected to pressure, the immediate suspension of the activity of the whole organ is the result; in this manner, a state resembling profound sleep can be induced in a moment, the normal activity being renewed *as* momentarily so soon as the pressure is withdrawn. This phenomenon has often been observed in the Human subject, in cases in which a portion of the cranial envelope has been lost by disease or injury. The various symptoms of Cerebral disturbance which are due to a state of general Plethora, are evidently owing to an *excess* of pressure within the vessels; but an undue diminution of pressure is no less injurious, as appears from the disturbance in the Cerebral functions which results from the very opposite cause, namely, a depression of the power of the heart, or a deficiency of blood in the vessels.—It is of peculiar importance to bear in mind the disturbance of the Cerebral functions, which is occasioned by internal *pressure*, when we are endeavouring to draw inferences from the phenomena presented by disease.

779. We shall now proceed with our Physiological inquiry into the functions of the Cerebrum; and shall, as before, apply to Human and Comparative Anatomy, to Experiment, and to Pathology, for our chief data.—The anatomical relations of the Cerebrum to the other Encephalic centres, clearly demonstrate that it is not one of the essential or fundamental portions of the Nervous system; but a superadded organ, receiving all its impulses to action from the parts below, and operating upon the body at large through them. And its great bulk, joined to its position at the summit of the whole apparatus,—the vesicular substance of its convolutions affording a termination to the fibres in connection with it, and not being merely traversed by them, as is the case with the vesicular substance of all the lower centres,—clearly mark it out as the highest in its functional relations, and as ministering, so far as any material instrument may do, to the exercise of those psychical powers, which, in Man, exhibit so remarkable a predominance over the mere animal instincts. This conclusion is fully borne out, when we extend our inquiries from Human to Comparative Anatomy; for with some apparent exceptions, which there would probably be no great difficulty in explaining if we were in possession of all the requisite data, there is a very close correspondence between the relative development of the *Cerebrum* in the several tribes of Vertebrata, and the degree of *Intelligence* they respectively possess,—using the latter term as a comprehensive expression of that series of mental actions, which consists in the *intentional* adaptation of means to ends, based on definite *ideas* as to the nature of both. It is the essential character of *Instinctive* actions, on the other hand, that they are performed automatically, in obedience to internal impulses, without even the perception of their adaptiveness on the part of the being who is the agent in them; these impulses being called into play by impressions on the nervous system, which are made either by external objects, or by changes in the individual organism. The justness of this distinction becomes obvious, when we analyse our

own consciousness, and distinguish our own Instinctive actions from those which involve Intelligence; for we are thus led to perceive that, in regard to those operations which are most closely concerned in the maintenance of our own lives and in the continuance of the race, provision has been made in the mechanism of the Automatic portion of our nervous system, so as to render them independent of the exercise of Intelligence or the exertion of Will on our own parts. Thus the infant seeks the nipple, and puts its muscles into suctorial action, without any knowledge that by so doing it will relieve the uneasy feeling of hunger; and if we could imagine a man coming into the world with the full possession of all his faculties, we may feel tolerably certain that he would not wait to eat until he had learned by experience his dependence upon food. We have seen that adult animals, whose Cerebral hemispheres have been removed, will eat food that is put into their mouths, although they will not go to seek it; and this is the case with many Human idiots. When the functions of the Brain are disturbed, or in partial abeyance, as in fever, we often see a remarkable return to the instinctive propensities in regard to food; and the Physician frequently derives important guidance as to the patient's diet and regimen (particularly as to the administration of wine), from the inclination or disinclination which he manifests. So, in regard to the intercourse of the sexes, the impulse which prompts to it does not arise from a knowledge of the ultimate purposes which it is designed to answer; and the higher powers of the mind are only so far concerned in it, that when the action of the instinctive impulse has led to the formation of a definite idea of the object of desire, the Intelligence is prompted to take means for its gratification.

780. It is not always easy to say, in the case of the lower animals, what parts of their actions are to be attributed to automatic impulses (*i.e.* to be considered as Instinctive), and what should be regarded as the results of Intelligence. Instinctive actions, however, may be generally distinguished from those which are directed by reason, by the following characters:—(1) Their unvarying *constancy* in the different individuals of the same species, and the absence of any such change during the progress of life or in the succession of generations, as indicates that the original plan of action has been intentionally departed-from: (2) by their occurrence under circumstances which altogether forbid the idea that any past experience can have suggested the design, or that in carrying it into effect there has been a gradual perfectionizing of the means; these actions being performed as well when first attempted, as after the most frequent repetition: (3) by their occasional performance under circumstances in which the least Intelligence would indicate their absurdity as being nugatory for the ends they are originally destined to accomplish; as when a tame Beaver attempts to build its dam across a room, or when a community of Bees, having killed their Queen because she only lays drone-eggs, attempts to make a new queen from one of the drone-larvæ. The character of Intelligent actions, on the other hand, is shown (1) in the *variety* of means which may be adopted to compass the same ends, and this not merely by different individuals and by successive generations, but by the same individual at different times; (2) by the improvement in the mode of accomplishing the object, which results from the intelligent use of experience, and from the greater command of means which

is progressively attained; and (3) by the conformity of the means to altered circumstances, so that the character of adaptiveness is still maintained, however widely the new conditions may depart from those which must be considered as natural to the species.

781. The difference between actions of a purely Instinctive character, and those which proceed from the Intellectual faculties prompted by the instinctive propensities, is well seen in comparing Birds with Insects. The Instinctive tendencies of the two classes are of nearly the same kind; and the usual arts which both exhibit in the construction of their habitations, in procuring their food, and in escaping from danger, must be regarded as intuitive, on account of the uniformity with which they are practised by different individuals of the same species, and the perfection with which they are exercised on the very first occasion. But in the adaptation of their operations to peculiar circumstances, Birds display a variety and fertility of resource, far surpassing that which is manifested by Insects; and it can scarcely be doubted by those who attentively observe their habits, that in such adaptations they are often guided by real Intelligence. This must be the case, for example, when they make trial of several means, and select that one which best answers the purpose; or when they make an obvious improvement from year to year in the comforts of their dwelling; or when they are influenced in the choice of a situation, by peculiar circumstances, which, in a state of nature, can scarcely be supposed to affect them. The complete domesticability of many Birds is in itself a proof of their possessing a certain degree of intelligence; but this alone does not indicate the possession of more than a very low amount of it; since many of the most domesticable animals are of the humblest intellectual capacity, and seem to become attached to Man, principally as the source on which they depend for the supply of their animal wants. But there are certain tribes of Birds, especially the Parrots and their allies, which possess an extraordinary degree of *educability*, and which manifest a power of performing simple acts of *reasoning*, that are quite comparable with those of a child when first learning to talk.—This development of the Intelligence under the influence of Man, and in accordance with *his* habits, rather than with the original habits of their species, is yet more remarkable in the case of those Mammals whose instincts lead them to attach themselves peculiarly to him, and whose powers of reasoning are called forth in adapting themselves to the new circumstances in which they are thus placed. The actions of a Dog, a Horse, or an Elephant are evidently the result, in many instances, of a complex train of reasoning, differing in no essential respect from that which Man would perform in similar circumstances; so that the epithet, "half-reasoning," commonly applied to these animals, does not express the whole truth; for their mental processes are of the same *kind* with those of Man, and differ more in the *degree* of control which the animal possesses over them than they do in their own character. We have no evidence, however, that any of the lower animals have a voluntary power of guiding, restraining, or accelerating their mental operations, at all similar to that which Man possesses; these operations, indeed, seem to be of very much the same character as those which we perform in our dreams, different trains of thought commencing as they are suggested, and proceeding according to the usual laws, until some other disturb them.—Although

it is customary to regard the Dog and the Elephant as the most intelligent among the lower animals, it is not certain that we do so with justice; for it is very possible that we are misled by that peculiar attachment to Man, which in them must be termed an instinct, and which enters as a motive into a large proportion of their actions; and that, if we were more acquainted with the psychical characters of the higher Quadrumana, we should find in *them* a greater degree of mental capability than we now attribute to them. One thing is certain, that the higher the degree of intelligence which we find characteristic of a particular race, the greater is the degree of variation which we meet-with in the characters of individuals; thus everybody knows that there are stupid Dogs and clever Dogs, ill-tempered Dogs and good-tempered Dogs,—as there are stupid Men and clever Men, ill-tempered Men and good-tempered Men. But no one could distinguish between a stupid Bee and a clever Bee, or between a good-tempered Wasp and ill-tempered Wasp, simply because all *their* actions are prompted by an unvarying instinct.

782. In estimating the relative development of the Cerebrum in different tribes of Animals, and in comparing this with their relative Intelligence, it must be borne in mind that the *size* of the organ does not, considered alone, afford a means of accurate judgment as to its *power*. For the quantity of vesicular matter which it contains, affords the only fair criterion of the latter; and of this we must judge, not merely by the superficial area, but by the number and depth of the convolutions, and by the thickness of the cortical layer. Again, there are many reasons why it is not fair to estimate the relative development of the Cerebrum by the proportion which it bears to the whole bulk of the animal; and, on the whole, the most accurate basis of comparison would probably be afforded by the relation between the bulk of the Cerebrum and the diameter of the Spinal Cord. In making any such comparison, however, the Thalami Optici, Corpora Striata, and Corpora Quadrigemina should be excluded from the estimate, for reasons now sufficiently apparent; and the bulk of the Cerebrum *proper* should be alone determined, either by weight, or by the displacement of liquid.— But the Cerebrum varies in different classes and orders of Vertebrata, not merely in proportional size, but also in the relative development of its anterior, middle, and posterior lobes. This is a point of very great importance, in determining the value to be assigned to the organological system of Gall and Spurzheim and their followers. The Cerebrum of the Oviparous Vertebrata is *not* a miniature representative of that of Man, as a whole, but only of his *anterior* lobes; as is sufficiently obvious from an examination of its connections with other parts, and from the absence of any other commissural connections between its two hemispheres, than those which are afforded by the Sensory Ganglia. It is in the Implacental Mammals that we find the first rudiment of the *middle* lobes of the Cerebrum, and of the proper intercerebral commissure, the Corpus Callosum; and even in the Rodents this is but very imperfectly developed. As we ascend the Mammalian series, we find the Cerebrum becoming more and more elongated posteriorly by the development of the middle lobes, and the intercerebral commissure becomes more complete; but we must ascend as high as the Carnivora before we find the least vestige of the *posterior* lobes; and the rudiment which these possess, and which is enlarged in the Quadrumana, only attains its

full development in Man, in whom alone the posterior lobes extend so far backwards as completely to cover-in the Cerebellum.*— The attention which has yet been given to this department of inquiry, has not hitherto done more than confirm the statement already made, with regard to the general correspondence between the development of the Cerebrum and the manifestations of Intelligence; very decided evidence of which is furnished by the great enlargement of the Cerebrum, and the corresponding alteration in the form of the Cranium, which present themselves in those races of Dogs most distinguished for their educability, when compared with those whose condition approximates most closely to what was probably their original state of wildness.

783. This general inference drawn from Comparative Anatomy, is borne-out by observation of the Human species. When the Cerebrum is fully developed, it offers innumerable diversities of form and size among various individuals; and there are as many diversities of character. It may be doubted if two individuals were ever exactly alike in this respect. That a Cerebrum which is greatly under the average size, is incapable of performing its proper functions, and that the possessor of it must necessarily be more or less idiotic, there can be no reasonable doubt. On the other hand, that a large well-developed Cerebrum is found to exist in persons, who have made themselves conspicuous in the world in virtue of their intellectual achievements, may be stated as a proposition of equal generality. In these opposite cases, we witness most distinctly the antagonism between the Instinctive and Voluntary powers. Those unfortunate beings, in whom the Cerebrum is but little developed, are guided almost solely by their instinctive tendencies; which frequently manifest themselves with a degree of strength, that would not have been supposed to exist: and occasionally new instincts present themselves, of which the Human being is ordinarily regarded as destitute.† On the other hand, those who have obtained most influence over the *understandings* of others, have always been large-brained persons, of strong intellectual and volitional powers, whose emotional tendencies have been subordinated to the reason and will, and who have devoted their whole energy to the particular objects of their pursuit.—It is very different, however, with those who are actuated by what is ordinarily termed *genius;* and whose influence is rather upon the *feelings* and *intuitions*, than upon the understandings, of others. Such persons are often very deficient in the power

* It has been asserted by the followers of Gall, that the development of the Cerebrum from behind forwards, as above described, is rather apparent than real; the whole organ being in fact pushed backwards by the excessive development of the anterior lobe. But the anatomical distinction between the anterior and middle lobes is sufficiently obvious externally; and that of the middle and posterior lobes is also clearly marked-out by the development of the posterior cornua of the lateral ventricles, and the situation of the hippocampus major. Hence the facts above stated do not admit of any such interpretation; and they are fully borne-out by the history of the Embryonic development of the Cerebrum in Man, which precisely follows the above plan.—It is not here denied that the anterior lobe of the Human Cerebrum is remarkable for its great extension *forwards;* but still, the difference between the Cerebrum of Man and that of the lower Mammalia consists much rather in the proportional development of the posterior lobes, than in that of the anterior.

† A remarkable instance of this was published some years since.—A perfectly idiotic girl, in Paris, having been seduced by some miscreant, was delivered of a child without assistance; and it was found that she had *gnawed* the umbilical cord in two, in the same manner as is practised by the lower animals. It is scarcely to be supposed that she had any idea of the *object* of this separation.

of even comprehending the ordinary affairs of life; and still more commonly, they show an extreme want of judgment in the management of them, being under the immediate influence of their passions and emotions, which they do not sufficiently endeavour to control by their intelligent will. The life of a 'genius,' whether his bent be towards poetry, music, painting, or pursuits of a more material character, is seldom one which can be held up for imitation. In such persons, the *general* power of the mind being low, the Cerebrum is not usually found of any great size.—The *mere* comparative size of the Cerebrum, however, affords no accurate measure of the amount of mental power; we not unfrequently meet with men possessing large and well-formed heads; whilst their physical capability is not greater than that of others, the dimensions of whose crania have the same general proportion, but are of much less absolute size. Large brains, with deficient activity, are commonly found in persons of what has been termed the *phlegmatic* temperament, in whom the general processes of life seem in a torpid and indolent state; whilst small brains and great activity, betoken what are known as the *sanguine* and *nervous* temperaments.

784. Having now inquired into the evidence of the *general* functions of the Cerebrum, which may be derived from examination of its Comparative development, we proceed to our other sources of information, Experiment and Pathological phenomena. From neither of these, however, is much positive information to be derived.—The results of partial mutilations are usually, in the first instance, a general disturbance of the Cerebral functions; which subsequently, however, more or less subsides, leaving but little apparent affection of the animal functions, except muscular weakness. The whole of *one* Hemisphere has been removed in this way, without any evident consequence, save a temporary feebleness of the limbs on the opposite side of the body, and what was supposed to be a deficiency of sight through the opposite eye. The former was speedily recovered-from, and the animal performed all its movements as well as before; the latter, however, was permanent, but the pupil remained active. When the upper part, only, of both Cerebral Hemispheres was removed by Hertwig, the animal was reduced, for fifteen days, to nearly the same condition with the one from which they had been altogether withdrawn; but afterwards, sensibility evidently returned, and the muscular power did not appear to be much diminished. — The effects of the entire removal of the Cerebral Hemispheres have been already stated (§ 734). So far as any inferences can be safely drawn from them, these fully bear out the conclusion, that the Cerebrum is the organ of Intelligence; since the animals which have suffered this mutilation appear to be constantly plunged in a profound sleep, from which no irritation ever seems able to arouse them into full activity, although they give manifestations of consciousness. It would be wrong hence to infer, however, as some have done, that such would be the natural condition of an animal without a Cerebrum; since it is obvious that much of the disturbance of the sensorial powers which is occasioned by this operation, is fairly attributable to the laying-open of the cranial cavity, to the disturbance of the normal vascular pressure, and to the injury necessarily done to the parts which are left, by their severance from the Cerebrum. Hence the persistence of consciousness, after the entire removal of the Cerebrum,—which

proves that the Cerebrum is *not* its seat, or at least *not its exclusive* seat,—is a far more important fact than the positive destruction of psychical power which is consequent upon the operation. So far as they can be trusted, however, the results of such mutilations bear out the views already put forth as to the superadded and non-essential character of the Cerebrum; and justify us in applying to the higher animals the inferences to which we should be led by the contemplation of those forms of the nervous system in which no Cerebrum exists. There is nothing, therefore, to oppose the conclusion, that whilst *sensations* may be felt, and sensori-motor actions excited, independently of the Cerebrum, the presence of this organ is essential to the formation of *ideas* or notions respecting the objects of sense, and to the performance of those psychical operations to which ideas furnish at once the material and the stimulus to activity.*

785. The information afforded by Pathological phenomena is equally far from being definite. Many instances are on record, in which extensive disease has occurred in *one* Hemisphere, so as almost entirely to destroy it, without either any obvious injury to the mental powers, or any interruption of the influence of the mind upon the body. But there is no case on record, of any such severe lesion of *both* hemispheres, in which morbid phenomena were not evident during life. It is true that, in Chronic Hydrocephalus, a very remarkable alteration in the condition of the Brain sometimes presents itself, which might *à priori* have been supposed destructive to its power of activity; the ventricles being so enormously distended with fluid, that the cerebral matter has seemed like a thin lamina, spread over the interior of the enlarged cranium. But there is no proof that absolute destruction of any part was thus occasioned; and it would seem that the very gradual nature of the change, gives to the structure time for accommodating itself to it. This, in fact, is to be noticed in all diseases of the Encephalon. A *sudden* lesion, that may be so trifling as to escape observation, unless this be very carefully conducted, will occasion very severe symptoms; whilst a chronic disease may gradually extend itself, without any external manifestation. It will usually be found that sudden paralysis, of which the seat is in the Brain, results from some slight effusion of blood in the substance or in the neighbourhood of the Corpora Striata; whilst, if it follow disorder of long standing, a much greater amount of lesion will usually present itself. In either case, the paralysis occurs in the opposite side of the *body*, as we should expect from the decussation of the Pyramids; but it may occur either on the same, or on the opposite side of the *face*,—the cause of which is not very apparent. If convulsions accompany the paralysis, we may infer that the Corpora Quadrigemina, or the parts below, are involved in the injury; and in this case it is usually found that the convulsions are on the paralysed side of the body,—the effect of the lesion, both of the Cerebrum and of the Corpora Quadrigemina, being propagated to the opposite side, by the decussation of the Pyramids. Where, as not unfrequently happens, there is paralysis of one side, accompanying convulsions on the

* It is worthy of remark, that M. Flourens, who in the first instance maintained that sensation is altogether destroyed by the removal of the Cerebrum, has substituted, in the Second Edition of his Researches, the word *perception* for *sensation;* apparently implying exactly what is maintained above.

other, it is commonly the result of a lesion affecting the base of the Brain and Medulla Oblongata, on the side on which the convulsions take place; here the effect of the lesion has to *cross* from the Brain, whilst its influence on the Medulla Oblongata is shown on the *same* side. Many anomalies present themselves, however, which are by no means easy of explanation, in the present state of our knowledge.—The disturbance of the Cerebral functions, occasioned by those changes in its nutrition which are commonly included under the general term of Inflammation, presents a marked diversity of character, according to the part it affects. Thus it is well known that the delirium of excitement is usually a symptom of inflammation of the cortical substance, or of the membranes of the hemispheres. This is exactly what might be anticipated from the foregoing premises, since this condition is a perversion of the ordinary mental operations, which are dependent upon the instrumentality of the vesicular matter: and it is evidently impossible for the membranes to be affected with inflammation, without the nutrition of this substance being impaired, since it derives all its vessels directly from them. On the other hand, inflammation of the fibrous portion of the Cerebrum is usually attended rather with a state of torpor, than with excitement; and with diminished power of the will over the muscles. It is stated by Foville, that in acute cases of Insanity, he has usually found the cortical substance intensely red, but without adhesion to the membranes; whilst in chronic cases, it is indurated and adherent: but where the insanity has been complicated with Paralysis, he has usually found the medullary portion indurated and congested.

786. The general result of such investigations is, that the Cerebrum is the instrument of all those *psychical* operations, which we include under the general term *Intellectual*, whilst it also affords, in part at least, the instrumental conditions of *Emotional* states (using this term in its widest sense); and that all those muscular movements which result from *voluntary* determinations, or which are directly consequent upon *emotional* excitement, have their origin in its vesicular substance, though the motor impulse is immediately furnished by the Automatic apparatus, upon which the Cerebrum plays (§ 757).—All the operations of the Mind are *originally* dependent upon the reception of *Sensations*. If it were possible for a Human being to come into the world, with a Brain perfectly prepared to be the instrument of psychical operations, but with all the inlets to sensation closed, we have every reason to believe that the Mind would remain dormant, like a seed buried deep in the earth. The attentive study of cases, in which there is congenital deficiency of one or more sensations, makes it evident that the Mind is utterly incapable of forming any definite ideas, in regard to those properties of objects, of which those particular sensations are adapted to take cognisance. Thus the man who is born blind can form no conception of colour; nor the congenitally-deaf, of musical tones. And in those lamentable cases, in which the sense of touch is the only one through which ideas can be introduced, it is evident that the mental operations must remain of the simplest and most limited character, if the utmost attention be not given by a judicious instructor, to the development of the intellectual faculties, and the cultivation of the moral feelings, through that restricted class of ideas which there is a possibility of exciting.—The activity of the Mind, then, is just

as much the result of its consciousness of external impressions, by which its faculties are called into play, as the Life of the body is dependent upon the appropriation of nutrient materials, and the constant influence of external forces. But there is this difference between the two cases,—that whilst the Body continually requires *new* materials and a continued action of external agencies, the Mind, when it has been once called into activity, and has become stored with ideas, may remain active, and may develope new relations and combinations amongst these, after the complete closure of the sensorial inlets by which new ideas can be excited *ab externo.* Such is, in fact, what is continually going on in the state of Dreaming; but examples yet more remarkable are furnished in the vivid conceptions which may be formed of a landscape or a picture, from oral description, by those who have once enjoyed sight; or in the composition of music, even such as involves new combinations of sounds, by those who have become deaf,—as in the well-known case of Beethoven. The mind thus feeds, as it were, upon the store which has been laid up during the activity of its sensory organs; but instead of diminishing, like material food, these ideas become more and more vivid, the oftener they are made the subjects of attention.

787. The seat of the *Sensational Consciousness*, as already shown, is indicated by a large mass of evidence to lie in the Sensory Ganglia, which are the real centres of the Nerves of Sense; and we may fairly conclude that, when not interrupted in the upward course already indicated, the changes which occur there give rise to a new excitement of nerve-force, which is propagated along the ascending nerve-fibres to the vesicular matter that forms the surface of the Cerebral Hemispheres; and that it is only when they arrive at the ultimate termination of these fibres in the latter, that these impressions give rise to those changes which are in the first instance instrumental in the formation of *Ideas,** and subsequently in the higher *Intellectual Operations.* These operations themselves become the source of new changes in the condition of the Nervous substance; and an excitation of nerve-force takes place as their result, which, transmitted downwards to the sensorial tract at the base of the Cerebrum, gives rise through it to respondent movements (§ 759).—Now it is an inquiry of considerable interest, both in its psychological and its

* The Author cannot here enter into the discussion which has been the subject of so many abstruse and laboured Metaphysical discussions, how far Ideas are to be considered as 'transformed sensations,' or as 'states or affections of the consciousness' which, though primarily *excited* by sensations, may have nothing in common with them. It will be sufficient for him to express his own conviction, that the latter is the only consistent mode of viewing the subject; and that the Idea can no more correctly be described as a 'transformed sensation,' than sensation itself could be designated as a transformed impression. The one is antecedent, the other consequent; the one is the force which, acting on a certain prepared organization, evokes a further change, just as a mechanical or electrical stimulus applied to a muscle calls it into contraction.—The notion of Condillac and the Sensational School of Psychologists, that ideas are 'transformed sensations,' appears to have been based upon the consideration of those ideas alone which are most nearly allied to Sensations in their nature, being the immediate psychical representations of objective or concrete realities. But it cannot be legitimately held of those *abstract* or *general* ideas, which have no objective representatives, and which are the products of mental operations that are by no means truly described by the term *transformation.* Thus the idea of the invariability of the *laws* of Nature arises out of a constant succession of new and diversified *phenomena;* as has been beautifully shown by Prof. Oersted, in his Essay on 'The Spiritual in the Material,' which forms the first section of his Treatise on "The Soul in Nature," recently given to the English public.

physiological relations, whether the Cerebrum is itself endowed with consciousness; that is, whether we become conscious of changes which take place in the condition of its substance, so long as these changes are limited to itself. At first sight it would appear to be a very startling proposition, that the organ of the intellectual operations is not itself endowed with consciousness; but a careful consideration of its relations to the Sensory Ganglia will tend to show that there is no *a priori* absurdity in such a notion. For if the relation of the vesicular matter of the Cerebral Hemispheres to the Sensorial Centres, be anatomically the same as that which is borne to these centres by the Retina, or by any other peripheral expansion of vesicular matter in an organ of sense, which we have seen that it is (§ 753),—and if the same kind of change may be excited in the Sensorial Centres by an impression from each source,

Fig. 137.


Diagram of the mutual relations of the principal Encephalic centres, as shown in a vertical section:—A, Cerebrum; B, Cerebellum; C, Sensori-motor tract, including the Olfactive ganglion *olf*, the Optic *opt*, and the Auditory *aud*, with the Thalami Optici *thal*, and the Corpora Striata *cs*; D, Medulla Oblongata; E, Spinal Cord;—*a*, olfactive nerve; *b*, optic; *c*, auditory; *d*, pneumogastric; *e*, hypoglossal; *f*, spinal: fibres of the medullary substance of the cerebrum are shown, connecting its ganglionic surface with the sensori-motor tract.

which has been shown to be a matter of common occurrence (§ 758),—it can scarcely be deemed unlikely that the Sensorial Centres should be the seat of consciousness, not merely of the impressions transmitted to them by the nerves of the external senses, but also of the impressions brought to them by the 'nerves of the internal senses,' as the sagacious Reil designated the radiating fibres of the Cerebral Hemispheres. And

* It is interesting to observe how remarkably this view is confirmed by the history of Development. For the Retina, like the cortical substance of the Cerebrum, is a vesicular expansion originally detached from the Sensory Ganglia, and gradually carried to a greater and greater distance from them; but still remaining connected by the commissural tract of white fibres, which we call in the one case the Optic Nerve, and in the other the Medullary substance of the Hemispheres.

there is on the other hand an *a priori* improbability that there should be *two* seats of consciousness, so far removed from one another as the Sensory Ganglia and the vesicular surface of the Hemispheres (for to their medullary substance no such attribute can be assigned with the least probability); an idea which is quite at variance with that very simple and familiar class of phenomena, which consists in the *recollection of sensations* (§ 812). For the remembered sensation is so completely the repetition of the original, that we can hardly suppose the seat of the two to be different; yet the act of recollection is clearly Intellectual, and therefore Cerebral; consequently, if we admit that the Sensory Ganglia are the seat of the original sensation, we can scarcely but admit that they are also the seat of that which is reproduced by a Cerebral act,—a view which is fully confirmed by the occurrence of automatic movements as consequences of its recal (§ 758). But further, we shall hereafter find evidence to the same effect, in our experience of the occasional evolution of results, such as ordinarily proceed from intellectual action, without any consciousness on our own parts of the steps whereby these are attained (§§ 813, 818, 819).

788. Without presuming, then, to affirm positively what cannot be proved, it may be stated as a probable inference from the Physiological facts already referred-to, and from the Psychological evidence hereafter to be adduced, that the Sensory Ganglia constitute the seat of consciousness, not merely for impressions on the Organs of Sense, but also for changes in the cortical substance of the Cerebrum; so that, until the latter have reacted downwards upon the Sensorium, we have no consciousness either of the formation of ideas, or of any intellectual process of which these may be the subjects. Ideas, emotions, intellectual operations, &c. have of late been frequently designated as 'states of consciousness;' and this psychological description of them is in full harmony with the physiological account here given of the material conditions under which they respectively occur. For a Sensation being a state of consciousness excited through the intermediation of the Sensorium, by a certain change (*e.g.*) in the condition of the Retina, it is not difficult to understand how a change in the condition of the Cerebrum may excite, through the same instrumentality, that state of consciousness which may be termed Ideational,* or that another change may produce the Emotional Consciousness, another the Intuitional Consciousness, another the Logical Consciousness. And although it may be thought at first sight to be a departure from the simplicity of Nature, to suppose that the Cerebrum should require another organ to give us a consciousness of its operations, yet we have the knowledge that the Eye does not give us visual consciousness, nor the Ear auditory consciousness, unless they be connected with the Sensory Ganglia; and in the end (the Author feels a strong assurance) it will be found much simpler to accept the doctrine of a common centre for *sensational*

* The Author ventures to use this term, the meaning of which requires no explanation, on the authority of Mr. James Mill, who remarks,—"As we say Sensation, we might also say Ideation; it would be a very useful word; and there is no objection to it, except the pedantic habit of decrying a new term. Sensation is the general name for one part of our constitution [or rather, for one state of our consciousness], Ideation for another." ("Analysis of the Human Mind," vol. i. p. 42.)—If the use of the substantive Ideation be admitted, there can be no reasonable objection to the adjective *ideational.*

and for what may be distinguished as *mental* consciousness, than to regard the two centres as distinct.*—We shall now proceed with a brief analysis of the operations of which the Cerebrum is the instrument; considering them in the ascending series, as founded upon Sensational changes.

789. Neither the operation of the Intellectual Powers, nor Emotional excitement, is *immediately* called-forth by the Sensational Consciousness; for if we do not advance beyond this, we merely recognize the fact that certain changes have occurred in our own 'subjective' state, and do not refer these changes to any external or 'objective' source. Of this we occasionally meet with examples among the phenomena of dreaming, and in some of the conditions resulting from the use of Anæsthetic agents; for if we fall asleep whilst suffering from bodily pain, we may entirely lose all perception of the cause of that pain as having its seat in our own bodily fabric, and yet remain conscious of a perturbed state of feeling; and when a surgical operation is performed in a state of incomplete Anæsthesia, it is obvious that pain is felt without any distinct consciousness of its source, and the patient may subsequently describe his state as an uneasy dream. Such, it is probable, is the condition of the Infant at the commencement of its psychical life. "If," as has been well remarked by Mr. Morell,† "we could by any means transport ourselves into the mind of an infant before the perceptive consciousness is awakened, we should find it in a state of absolute isolation from everything else in the world around it. Whatever objects may be presented to the eye, the ear, or the touch, they are treated simply as subjective feelings, without the mind's possessing any consciousness of them *as objects* at all. To it, the inward world is *everything*, the outward world is *nothing*."—However difficult it may be, under the influence of our life-long experience, to dissociate any sensation which we experience from the idea of its external cause—since, the moment the feeling is experienced, and the mind is directed to it, the object from which it arises is immediately suggested,—yet nothing is more certain than that all of which we are ourselves conscious, in any case whatever, is a certain internal or subjective state, a change in our previous consciousness; and that the formation of the idea of the object to which that change is due, is dependent upon a higher mental process, to which the name of *Perception* or *Perceptive Consciousness* is now generally accorded.‡ We may recognize the manifestation of this process in the child, as it advances beyond the first few months of its helplessness. "A sight or a sound," remarks Mr. Morell (Op. cit.), "which at first produced simply an involuntary start, now awakens a smile or a look of recognition. The mind is evidently struggling *out of itself;* it begins to throw itself into the objects around, and to live in the

* It may serve to give additional confidence in the views above propounded, if the Author mentions that he was led by them to *predict* the psychological phenomena referred-to at the end of § 787, of which he was not at the time aware as facts, but of which he afterwards became assured by the analysis of his own consciousness, and by the communicated experience of others to whom he stated the question.

† "Philosophy of Religion," p. 7.

‡ For the attachment of this definite meaning of the term Perception, as for many other services to Psychological Science, we are indebted to Sir William Hamilton.—See especially his note on the 'Philosophy of Sensation and Perception,' in his edition of the "Works of Dr. Reid."

world of outward realities." We may recognize a similar transition, more rapidly effected, during the passage from sleep, or from the insensibility of a swoon, to the state of complete wakefulness; when we are at first conscious only of our own sensations, and gradually come to the knowledge of our condition as it relates to the world around, and of the position and circumstances, new and strange as they may be, in which we find ourselves.

790. Now the elementary notion of the *outness* or *externality* * of the cause of sensational change, is undoubtedly formed by a law of our mental nature; and must be regarded as a mental instinct or *intuition.* We do not *infer* the existence of objective realities by any act of the reason; in fact, the strict application of logical processes tends rather to shake than to confirm the belief in the external world; but the qualities of matter are directly and immediately recognized by our minds, and we then go on to shape the information we have thus acquired, into a definite notion of the object. Some of these notions are so simple, and so constantly excited by certain sensations, that we can scarcely do otherwise than attribute their formation to original and fundamental properties of the mind, called into activity by the sensations in question; thus, as we shall hereafter see (CHAP. XV. Sect. 5), the notion of the *projection* or *solidity* of an object is necessarily developed in our minds, when two pictures having certain relations of *dis*similarity are projected on our two retinæ. But in other cases, the ideas are connected with the sensations by habit alone; and it is entirely due to the association which has been gradually formed between them, that the one calls up the other. Of this we have a valuable illustration in the process by which we acquire a language. A certain sound comes to be connected in the mind of the child with a certain object, its knowledge of which is derived through the visual or other sense; and by the habitual recurrence of this connection, the sensational consciousness of the sound comes to suggest the idea of the object, so that the notion of bread or of water is at once called-up by the mention of their names; whilst, on the other hand, the idea of the object reproduces that sensational consciousness of the sound of its name, which is the necessary guide in the pronunciation of the word. And the adult, in learning a new language, goes through a process of a very similar kind; the association being first formed between *its* words and the words of the language already familiar to him, and the former at last directly suggesting the corresponding ideas, without any necessity for the intermediate process of translation. On the other hand, the sight or the sound of the words of a language altogether unknown to us, excites no other respondent idea in our minds, than that which arises out of the simple act of perception; namely, the externality of the object which has impressed our sense of vision or of hearing. But the case is different with regard to those signs which are the *natural* expressions of ideas; for, in so far as they are so, they *intuitively* suggest those ideas to the mind of another. This, however, is much more noticeable with regard to the signs of *emotional* states,—which are very early interpreted by children, and

* This term is to be understood in the present inquiry, as implying what is external to the *mind.* Viewed in that aspect, the bodily organism stands in the same kind of relation to it, as does the world beyond; and the changes in the former which give rise to sensations, are as much *objective* as are those of the latter.

also by the lower animals,—than with respect to those which express *simple ideas.**

791. We have seen that, for the production of a Sensation, a *conscious* state of mind is all that is required; whilst, on the other hand, for the exercise of the Perceptive power, a certain degree of *attention* is requisite; or, in other words, the Mind must be *directed towards* the sensation. And thus it happens that, owing either to the inactivity of the Cerebrum, or to the complete engrossment of the mind by some other subject of thought, the sensation may neither be perceived nor remembered, notwithstanding that we have evidence, derived from the respondent movements of the body, that it has been felt. Thus a person in a state of imperfect sleep may start at a loud sound, or may turn away from a light shining on his face; being conscious of the sensation, and acting automatically upon it, but having no consciousness whatever of the object which gave rise to it. And, in like manner, a person in a state of profound abstraction may perform many automatic movements (§ 749), which cannot (so far as we know) be excited except through the medium of sensation; and yet the exciting sensations are neither perceived by him at the time, nor are they afterwards remembered; so that, when he is aroused from his reverie, he may be astonished to find himself in circumstances altogether different from those under which he passed into it. Sometimes, however, the sensorial impression may excite a sort of imperfect perception, which is subsequently remembered and completed. For example, the student who does not hear the repeated strokes of the clock when his mind is entirely given-up to his object of pursuit, may have a sort of vague consciousness of them if his attention be less completely engrossed by his studies; and although the sounds may not suggest at the moment any distinct idea of the passage of time, yet, when he subsequently gives his attention to the sensorial impression, he may remember to have heard the clock strike, and may even be able to retrace the number of strokes.† When the attention is directed, however, to the sonorous impressions (as when we are *listening* for the striking of the clock), or when it is not so closely fixed on any other object as that it may be attracted by the sensations, the sounds are not only recognized as proceeding from an external source, which is a simple act of Perception, but, by a mental act which depends upon previous associations, the sounds give rise to the

* The deaf and dumb are trained to communicate with each other, not merely by the 'finger-language,' by which words are alphabetically spelled, but also by the 'sign-language,' by which ideas are conveyed through the much more direct medium of single signs. These signs, though partly conventional, are made to conform as nearly as possible to the *natural* expressions of ideas; and are usually acquired very quickly by the deaf and dumb, whose want of other modes of utterance forces into activity a mode of expressing their ideas and emotions, which is unnecessary to those who have the command of language, and is consequently but little exerted by them. Young children, however, who associate much with the deaf and dumb, very readily acquire this 'sign-language,' and will often prefer the continued use of it to the acquirement of *spoken* language.

† It is curious that in so retracing a number, we are often assisted by mentally reproducing the succession of strokes, *imagining* their recurrence, until we feel that we have counted-up to the impression that was left upon our sensorium. In the same way, if asked how many stairs there are in a stair-case which we are in the habit of using, we may not be able to name the number; yet, when actually ascending or descending, we are conscious that we have arrived at the top or the bottom, by the completion of that series of sensorial changes which has become habitual to us.

complex idea of the striking of a clock, and are referred, it may be, to some particular clock. Hence, when we say (as we commonly do) that we have heard the clock strike, we affirm that which is not strictly correct; for that which we hear is simply the series of sounds, and it is by an intuitive perception that we are led to consider those sounds as originating in an external object; whilst the formation of a definite notion with regard to the nature of that object, is an act of judgment and comparison, guided by past experience. When such an operation has been very frequently performed, however, the notion comes to be so directly excited by the sensation, that it is uniformly and necessarily called-up when the attention is directed to the latter; the individual being quite forgetful of the mental process by which this connection was originally established.

792. Thus the formation of what have been designated as *acquired* perceptions, in contradistinction to those of the *intuitive* kind, bears a striking analogy to the process by which habitual movements come to be linked-on to the sensations that prompt them, so as at last to be automatically performed, although originally guided by the Will (§ 749). And it can scarcely be regarded as improbable, that, in the one case as in the other, the nervous mechanism *grows-to* particular modes of activity (§ 726); so that successions of action are uniformly excited by particular stimuli, which were not provided-for in its original construction. Such a view harmonizes well with the fact, that such associations, both between sensations and respondent *movements*, and between sensations and respondent *ideas*, are formed much more readily during the period of childhood and adolescence, than they are after the full measure of development has been attained; and that they are much more durable in the former case than in the latter. For that which has been already pointed out with regard to the nutrition of other tissues (§ 591), may not unreasonably be applied to that of the Nervous system; that, when once a certain mode of nutrition has been fully established, it tends to perpetuate itself, provided that it be not altogether unconformable to the original type. Throughout the whole constitution of Man, physical and mental, we witness this capacity of adaptation to a great variety of circumstances; and it seems to be purposely left to Man to educate himself in accordance with those circumstances; so that he gradually *acquires* those modes of action, which in other animals are directly prompted by instinctive or intuitive tendencies. The idea of the distance of an object, for example, is one derived in Man from many sources, and is the result of a long experience; the infant, or the adult seeing for the first time, has to bring the senses of sight and of touch to bear upon one another, in order to obtain it; but, when once the power of determining it is acquired, the steps of the process are lost sight of. In the lower tribes of animals, however, in which the young receive no assistance from their parents, there is an evident necessity for some *immediate* power of forming this determination; since they would not be able to obtain their food without it. Accordingly, they manifest in their actions a perception or governing idea of distances, which can only be gained by Man after long experience. A fly-catcher, for instance, just come out of its shell, has been seen to peck at an insect, with an aim as perfect as if it had been all its life engaged in learning the art. — In some cases, animals seem to learn that by intuitive percep-

tion, at which Man could only arrive by the most refined processes of reasoning, or by the careful application of the most varied experience. Thus, a little fish, named the *Chætodon rostratus*, is in the habit of ejecting from its prolonged snout, drops of fluid, which strike insects that happen to be near the surface of the water, and cause them to fall into it, so as to come within its own reach. Now by the laws of refraction of light, the place of the Insect in the air will not really be that at which it appears to the Fish in the water; but it will be a little below its apparent place, and to this point the aim must be directed. But the difference between the real and the apparent place will not be constant; for the more perpendicularly the rays enter the water, the less will be the variation; and, on the other hand, the more oblique the direction, the greater will be the difference. Now it is impossible to imagine but that, by an intuitive perception, the real place of the Insect is known to the Fish in every instance, as perfectly as it could be to the most sagacious Human mathematician who might determine it in each case by a process of calculation, or to a clever marksman who had learned it practically by a long experience.

793. Just as the simple feelings of pleasure or pain are associated with particular sensations (§ 759), the same feelings connect themselves with particular *Ideas;* and thus are produced those *Emotional* states of mind, which, directly or indirectly, determine a great part of our habits of thought, and are largely concerned in the government of our conduct. The formation of a true *desire,* even for the gratification of some bodily appetite, requires that an idea of the object of desire shall have been formed; and it is the expectation of the pleasure which will arise from the performance of the act in question, or of the pain which will be produced by abstinence from it, which makes the idea a *motive* to action. A careful analysis of the various Propensities, Moral Feelings, Sentiments, &c., which are ranked by Metaphysicians under the general term 'active principles,' will show (the Author believes) that such is the essential nature of all. Thus, Benevolence is the pleasure in the happiness of others; and shows itself alike in the habitual entertainment of the abstract or general idea, and in the direction of the conduct in any particular instance. So there is a positive pleasure, in some ill-constituted minds, in the contemplation of the *un*happiness of others; and this we designate as Malevolence. Again, the Combativeness of Phrenologists is nothing else than the pleasurable idea of setting one's self in antagonism with others; which may manifest itself either physically or psychically, according to the temperament of the individual.* So, Pride (or self-esteem) consists in the pleasurable contemplation of our own superior excellencies; whilst the essence of Vanity (or love of appro-

* There are individuals who never manifest the least degree of *physical* combativeness, who yet show a remarkable love of opposition in all their *psychical* relations with others. That objections will be raised by such persons to *any* plan that may be proposed, we can always feel sure, though we may not have the remotest idea as to what the objection may be in each particular case. Persons in whom this tendency exists in a less prominent degree, are apt to see objections and difficulties *first,* although their good sense may subsequently lead them to consider these as of less account, or to be outweighed by the advantages of the scheme. Such was the case with the late Sir Robert Peel. On the other hand, those who are spoken of as of *sanguine* temperament, are apt to lose sight of the intervening difficulties, in the pleasurable idea of the *result.*

bation) lies in the pleasurable idea of the applause of others. Again, in Conscientiousness we have the love of right, that is, the association of pleasure with the idea of right; Veneration may be defined as the pleasurable contemplation of rank or perfections superior to our own; and the source of Ambition, which is in some degree the antagonistic tendency, lies in the pleasurable idea of self-exaltation. In like manner, Hope is the pleasurable contemplation of future enjoyment; Fear is the painful contemplation of future evil; and Cautiousness is the combination of the desire to avoid anticipated pain with the pleasurable contemplation (an extremely strong feeling in many individuals) of precautions adapted to ward it off.—The same view may be applied to the love of Truth, of Beauty, of Sublimity, of Goodness, of Order, of Possessions, of Country, &c.; and also to Cheerfulness, Wit, Humour, &c., and to many conditions usually considered as purely Intellectual. And, in fact, the association of *sensorial pleasure* with *any idea*, or *class of ideas* gives to it an Emotional character; so that the Emotional states are not by any means limited within the categories which most Psychologists have attempted to lay down; these being, for the most part, *generic terms*, which comprehend certain groups of ideas bearing more or less similarity to each other, but not by any means including all possible combinations.*—By those who regard the Propensities, Moral Feelings, &c., as simple states of mind, it is usually said that their indulgence or exercise is attended with pleasure, and the restraint of them with pain. But, if the view here taken be correct, it is the very co-existence of pleasurable or painful feelings with the idea of a given object, that causes desire or aversion as regards that object; since the mind instinctively pursues what is pleasurable and avoids what is painful. And thus, according to the readiness with which these different classes of ideas are excited in different minds (partly depending upon original constitution, and partly upon the habitual direction of the thoughts), and to the respective degrees in which they respectively call forth the sensorial feelings of pleasure or pain (as to which there is obviously an inherent difference amongst individuals, analogous to that which exists with regard to the feelings of pleasure or pain excited by external sensations, sights, sounds, tastes, odours, or contacts), will be the disposition of the mind to entertain them, the frequency with which they will be brought before the mental view, and the influence which they will exert in the determination of our conduct.†

* The truth of this statement must be apparent to all who are familiar with the manifestations of Eccentricity and Insanity; for we frequently see pleasurable feelings associating themselves with ideas, which to ordinary minds appear *indifferent* or are even regarded with pain; and thus are engendered motives, which exert a most powerful influence over the conduct, and which, if not kept in restraint by the Will, render the whole being their slave.—It may be also remarked, in this place, that the impossibility of classing all the Emotional states of mind under a limited number of categories, constitutes a most serious and fundamental objection to any system, which professes to mark-out in the Cerebrum distinct seats for the Animal Propensities, Moral Feelings, &c.

† The above view of the nature of Emotional states was first developed by the Author in an article on the 'Physiology of the Brain' in the "British and Foreign Medical Review," October, 1846.—It was not until he had thought-out the subject for himself, on the physiological basis which is here given to it, that his attention was directed to Mr. James Mill's masterly "Analysis of the Human Mind," as containing a very similar doctrine. It has been a great satisfaction to him to find that a Metaphysician of so high a rank had anticipated his conclusions, and this upon psychological grounds only; since it gives him the more con-

794. The influence of Emotional conditions, when strongly excited, in directly producing involuntary movements, is readily explained on the idea that the Sensory Ganglia are the seat of all consciousness, and the Cranio-Spinal axis the real source of all movement. For there is no more difficulty in understanding that the excitement of peculiar states of consciousness in the Sensorial centres through the instrumentality of the Cerebrum, should give rise to automatic movements, than that such movements should follow similar states of consciousness when excited by impressions made upon the organs of vision, hearing, &c. And the correspondence is seen to be very close, when the idea (as is doubtless the case in some instances) is very nearly akin to the sensation. Thus, the laughter excited by the act of tickling, is a purely consensual movement (§ 748); but, in a very 'ticklish' person, the mere *idea* of tickling, suggested by pointing a finger at him, is sufficient to provoke it. So, again, laughter may be excited by odd sights or sounds which do not in themselves excite any emotional state, and which we call 'ludicrous' merely because they *do* excite laughter; and the vivid recollection of these, being attended with a state of the sensorium corresponding to that produced by the sensation, may give rise to the same involuntary cachinnation. But Laughter may also be excited by ideas that are much more removed from actual sensations, as, for example, by those unexpected combinations of ideas of a purely intellectual nature, which we designate as 'witty;' and here, too, we may recognise the very same *modus operandi*. For the mere sound or sight of the *words* excites no feeling of the ludicrous; the *sensation* must develope an *ideational* change; and it is the latter alone, which, reacting downwards upon the Sensorium, and there becoming associated with the feeling of pleasure, gives rise to the impulse to laugh. The same might be shown to be the case with regard to the act of Crying; which may be either purely consensual, being excited by painful sensations; or may be induced by the vivid recollection of past or the anticipation of future sensations; or may be excited by ideas which have no direct relation to sensational states. Again the movements which take place under the violent excitement of the passions of Anger, Lust, &c., are of the same involuntary character; being directly prompted by feelings which may be either excited by external sensations, or by internal ideas more or less akin to them. Thus the passionate man who receives a blow, instinctively makes another blow in the direction from which it seemed to him to come, without any thought of whether the blow was accidental or intentional; and the idea of an

fidence in the truth of the physiological doctrines with which he has connected them. His principal point of difference from Mr. Mill, lies in the greater difference which he believes to exist between *ideas* and *sensations;* for he cannot, with Mr. Mill, regard an Idea as a mere "trace or copy of the sensation, which remains after the sensation ceases," but must consider it as a state of mind altogether different, excited or induced by sensations; and consequently, he does not consider the emotional state to consist in the anticipation of a future pleasurable *sensation*, since the pleasure is generally associated with *ideational states* which have no analogy whatever to the sensations which excited them. Thus the Love of Praise does not consist in the association of pleasure with the auditory or visual sensations produced by spoken or written *words;* but in the association of pleasure with the *ideas* which these words call forth in the mind.—A view of the nature of the Emotional states which approaches more nearly to his own, though not developed with the analytical precision of Mr. Mill's, is contained in the Rev. Sydney Smith's "Lectures on Moral Philosophy;" which, although delivered early in the present century, were not published until the year 1850.

insult, which is a source of mental disturbance, may excite the very same movement, although no bodily suffering had been experienced. In states of excessive sexual excitement, again, the desire, which arises out of the idea of the object (§ 772), produces involuntary movements corresponding to those which are ordinarily linked-on to the actual sensations alone. There are many of the movements of Expression, which are referable in like manner to states of consciousness, whether pleasurable or painful, which may arise either from sensational or from ideational conditions. Thus the Cheerful aspect of some individuals is due to a sense of general *physical* well-being, and is altogether discomposed by anything which disturbs this; whilst, on the contrary, it proceeds in others from a happy frame of mind (which may be partly the result of original constitution, and partly of habitual self-direction), disposing them to take the cheerful view of everything that affects themselves or others, notwithstanding (it may be) great bodily discomfort. And the reverse aspect of Gloom may in like manner proceed alike from bodily or from mental uneasiness.—All these facts point, therefore, to the *singleness* of the centre from which the Emotional movements immediately proceed; and to its identity with the centre of the Sensori-motor actions.

795. That the Emotional and Volitional movements, however, differ as to their primal sources, is obvious, not merely from the fact that they are frequently in antagonism with each other,—the Will endeavouring to restrain the Emotional impulse, and either succeeding in doing so, or being vanquished by the superior force of the latter,—but also from the curious fact, which Pathological observation has brought to light, that muscles which will still act in obedience to emotional impulses may be paralysed to the volitional, and *vice versâ.* Thus for example, the arm of a man affected with hemiplegia, which no effort of his will could move, has been seen to be violently jerked under the influence of the mental agitation consequent upon the sight of a friend. And in the case of softening of the Spinal Cord already referred-to (§ 704 *note*), the choreic movements, which were brought on by the mere approach of any one to the patient's bed, and still more strongly by putting a question to him, were most violent in the lower limbs, over which he had not the least voluntary power.—It is in the different forms of paralysis of the Facial nerve, however, which is the one most peculiarly subservient to the movements of Expression, that we have the best evidence of this distinctness. For it sometimes happens that the muscles supplied by this nerve are paralysed so far as regards the Will, and yet are still affected by Emotional states of mind, and take their usual part in the automatic actions of Respiration, &c., retaining also their usual tension, so that no distortion is apparent unless Voluntary movements be attempted: thus, to select an action which may be performed either consensually, emotionally, or voluntarily, a patient affected with this form of paralysis cannot close the eyelid by an act of his will, although he winks when he feels the uneasy sensation that excites the action, and shuts the lids when the sudden approach of an object to the eye excites the fear of injury to that organ. On the other hand, the paralysed condition may exist in regard to the automatic and emotional actions only, so that the muscles lose their tension, the mouth is drawn to one side, the movements of expression are not performed, and there is no involuntary winking:

yet the Will may still exert its accustomed control, and may produce that closure of the lids which does not take place in respondence to any other impulse.*—It has been inferred by Dr. M. Hall,† from cases of this kind, that the Emotional actions are among those which are performed by his 'true spinal' system of nerves, as distinct from the sensori-volitional, and that they therefore fall under the general category of excito-motor actions. But it is obvious that they differ from these in their dependence, not merely upon sensations, but also upon higher states of mind; and there is no proof whatever, that the same nerve-fibres do not serve for the conduction of the motor impulses proceeding from the two different mental sources, Volition and Emotion, as we have seen that they probably do for the volitional and automatic impulses (§ 753).‡

796. The Emotions are concerned in Man, however, in many actions, which are in themselves strictly voluntary. Unless they be so strongly excited as to get the better of the Will, they do not operate downwards upon the Automatic centres, but upwards upon the Cerebral; supplying the *motives* by which the course of thought and of action is habitually determined. Thus, of two individuals, with differently constituted minds, one shall judge of everything through the medium of a gloomy morose temper, which, like a darkened glass, represents to his judgment the whole world in league to injure him; and his determinations being all based upon this erroneous view, its indications are exhibited in his actions; which are themselves, nevertheless, of an entirely voluntary character. On the other hand, a person of a cheerful, benevolent disposition, looks at the world around as through a Claude Lorraine glass, seeing everything in its brightest and sunniest aspect; and, with intellectual faculties precisely similar to those of the former individual, he will come to opposite conclusions; because the materials which form the basis of his judgment, are submitted to it in a very different condition. Various forms of Moral Insanity exhibit the same contrast, in a yet more striking light. We not unfrequently meet with individuals, still holding their place in society, who are accustomed to act so much upon *impulse*, and to be so little guided by *reason*, as to be scarcely regarded as sane; and a very little exaggeration of such a tendency causes the actions to be so injurious to the individual himself, or to those around him, that restraint is required, although the intellect is in no way disordered, nor are any of the feelings perverted. Not unfrequently we may observe similar inconsistencies, resulting from the habitual indulgence of one particular feeling, or a morbid exaggeration of it. The mother who, through weakness of will, yields to her instinctive fondness for her offspring, in allowing it gratifications which she knows to be injurious to it, is placing herself below the level of many less gifted beings. The habit of yielding to a natural

* See the detailed accounts of such cases in Sir C. Bell's work on "The Nervous System of the Human Body;" also "Brit. and For. Med. Rev.," vol. iv. p. 500, and vol. xiii. p. 553.

† "Memoirs on the Nervous System," 1837, pp. 94, et seq.

‡ In former editions of this Treatise, the Author maintained, upon the principles advocated by Dr. M. Hall, that there must be distinct centres and conducting fibres for Volitional, Emotional, and Reflex movements. Having since arrived at what he believes to be a much simpler explanation of the phenomena, and one more in accordance with the facts of the case, he does not hesitate to make known the change in his convictions; and would hope that he may induce those who may have adopted his previous opinions, to reconsider the subject under the aspect in which he has now placed it.

infirmity of temper often leads into paroxysms of ungovernable rage, which, in their turn, pass into a state of maniacal excitement. It is not unfrequently seen, that a delusion of the *intellect* (constituting what is commonly known as Monomania) has in reality resulted from a disordered state of the *feelings*, which have represented every occurrence in a wrong light to the mind of the individual. All such conditions are of extreme interest, when compared with those, which are met with amongst idiots, and animals enjoying a much lower degree of intelligence: for the result is much the same, in whatever way the balance between the feelings and the judgment (which is so beautifully adjusted in the well-ordered mind of Man) is disturbed; whether by a diminution of the Voluntary control or by an undue exaltation of the feelings and passions.

797. This double *modus operandi* of the Emotional consciousness,—*downwards* through the nerve-trunks upon the muscular apparatus, and also upon many of the Organic functions (CHAP. XVIII.),—and *upwards* upon those Cerebral actions which give rise to the higher states of Mental consciousness,—affords a satisfactory explanation of a fact which is practically familiar to most observers of Human nature; namely, that violent excitement of the feelings most speedily subsides, when these unrestrainedly expend themselves (so to speak) in their natural expressions. Thus it may be commonly noticed that those who are termed *demonstrative* persons are less firm and deep in their attachments, than those who manifest their feelings less; for, without any real insincerity or intentional fickleness, the strongly excited feelings of the former are rapidly calmed-down by the expenditure of the impulse to action which they have generated; whilst in the latter the very same feelings acting internally acquire a permanent place in the psychical nature, and habitually operate as motives to the conduct. So, again, persons who are 'quick-tempered,' manifesting great irascibility upon small provocations, real or supposed, are usually soon appeased, and soon forget the affront; whilst those who make little or no display of anger, are very apt to brood over and cherish their feelings of indignation, and may visit them upon the unfortunate object of them, when some favourable opportunity happens to occur, long after he had supposed that the occurrence which had given rise to them was forgotten. There is an instinctive restlessness, or tendency to general bodily movement, in some individuals, when they are suffering under emotional excitement; the indulgence of which appears to be a sort of safety-valve for the excess of nerve-force, whilst the attempt at its repression is attended with an increase in the excitement. Most persons are conscious of the difficulty of sitting still, when they are labouring under violent agitation, and of the relief which is afforded by active exercise; and this is particularly the case when the movements are such as naturally express the passion that is excited. Thus the combative propensities of the Irish peasant commonly evaporate speedily with the free play of the shillelagh; many irascible persons find great relief in a hearty explosion of oaths, others by a violent slamming of the door, and others (whose excitement is more moderate, but less transient) in a prolonged fit of grumbling.* So, again, if a ludicrous idea be suggested to our

* This view is most fully confirmed by certain phenomena of Insanity. It is a doctrine now generally received among practical men, that paroxysms of violent emotional excitement

consciousness, occasioning an impulse to laugh, a hearty cachinnation generally works-off the excitement, and we may be surprised a short time afterwards that such an absurdity should have provoked our risibility; but if we restrain the explosion, the idea continues to 'haunt' us, and is continually perturbing our trains of thought until we have given free vent to the expression of it. It is well known, again, that the depressing emotions are often worked-off by a fit of crying and sobbing; and the 'relief of tears' seems manifestly due to the expenditure of the pent-up nerve-force, in the production of an increased secretion. It is noticed in this case, too, that the absence of any such external manifestations of the depressing emotions, gives them a much greater influence upon the course of thought, and upon the bodily state of the individual. Those who really 'die of grief,' are not those who are loud and vehement in their lamentations, for *their* sorrow is commonly transient, however vehement and sincere while it lasts; but they are those who have either designedly repressed any such manifestations, or who have experienced no tendency to their display; and their deep-seated sorrow seems to exert the same kind of anti-vital influence upon the organic functions, that is exercised more violently by 'shock;' producing their entire cessation without any structural lesion.*

798. Like the other sources of motor activity which have been already treated-of, the Emotional tendencies may become morbidly excited, so as to produce a variety of movements which the Will vainly attempts to control. Of this abnormal condition there are several varieties. The most common is the *Hysterical* state (most frequent among females, though not peculiar to them) in which smiles and cries, laughter and sobbing, are strangely intermingled, and are brought on by the slightest emotional excitement. Now here the deficiency lies rather in the power of voluntary direction of the *thoughts*, than in the power of the will over the *muscles;* for such patients can be caused to restrain themselves, either

are much more likely to subside, when they are allowed to 'work themselves off' freely, without any attempt at mechanical restraint; and maniacal patients are now placed, in all well-managed Asylums, in padded-rooms, in which their movements can do no injury to themselves or others.—The following case was related to the Author by his friend Dr. Howe, of Boston, N.E., the instructor of Laura Bridgman. A half-idiotic youth in the Lunatic Asylum of that place was the subject (like many in his condition) of frequent and violent paroxysms of anger; and with the view of moderating these, it was suggested that he should be kept for some time every day in rather fatiguing exercise. Accordingly he was employed for two or three hours daily in sawing wood, to which task he made no objection; and the paroxysms of rage never displayed themselves except on Sundays, when his employment was intermitted. It having been considered, however, that it was better for him to spend part of that day in sawing wood, than to be irascible during the whole of it, his occupation was continued through the whole week, when he became completely tamed-down, and never gave any more trouble by his passionate displays.—This case appears to the Author a most valuable confirmation of the doctrine laid down in the text; which is one whose practical bearings are most important.

* The Author once heard the following singular case of this kind.—One of two sisters, orphans, who were strongly attached to each other, became the subject of consumption; she was most tenderly nursed by her sister during a long illness; but on her death, the other, instead of giving way to grief, in the manner that might have been anticipated, appeared perfectly unmoved, and acted almost as if nothing had happened. About a fortnight after her sister's death, however, she was found dead in her bed; yet neither had there been any symptoms during life, nor was there any post-mortem appearance, which in the least degree accounted for this event, of which no explanation seems admissible, except the depressing influence of her pent-up grief upon her frame generally, through the nervous system.

by the presentation of some powerful motive (as the threat of severe discipline in the event of the return of the paroxysm), or by the more gradual exercise of the power of the Will in repressing the first access of emotional excitement by the withdrawal of the mind from the contemplation of all that induces it. For in such individuals, the involuntary movements are but the expression of an unhealthy state of Mind; in which, either from an injudicious system of education, or from habitual want of self-control on the part of the individual, the emotions are allowed to exercise unchecked domination; and in which the Will is at last so weakened, that the subject of the disorder can scarcely be considered as a responsible being.—There are other Hysterical cases, again, in which there is less of mental disorder, but a greater physical excitability of the nervous system; so that most violent paroxysms of a tetanic or epileptic character are induced by very slight stimuli; and any emotional excitement may act as one among these stimuli, without, however, being at all excessive in its amount. Here, too, the Will may have a perfect control over the muscles, at all other times than when they are thrown into violent action by the reflex excitability of the Automatic centres; and the treatment of such cases must be in great degree directed to the removal of such excitability, which frequently depends upon some morbid condition of the uterus or ovaries. At the same time, there is no doubt that an habitually perturbed state of the emotions, and especially of those relating to sexual love, has a most decided influence both in first inducing and in subsequently maintaining this automatic excitability; and that whilst mental tranquillity and self-regulation are almost essential to recovery, nothing promotes it so much as the supervention of a more favourable state of feeling, arising out of the prospective realization of desires repressed or of hopes deferred.—But there are other states in which Emotional excitement has a morbid power of inducing muscular movements; and this not through any deficiency of due control over the feelings, but often concurrently with a want of power to bring the Will to bear upon the muscles. This condition in its extreme form is known as *Chorea*, the nature of which will be hereafter examined more minutely; at present it will be sufficient to refer to some of those slighter forms of it, which have received no definite appellation. Thus, there are individuals not at all remarkable for their emotional excitability, who cannot avoid making the most extraordinary grimaces whenever anything happens which in the least disturbs their usual equanimity, notwithstanding that they may make all the efforts in their power to prevent these.* The general muscular agitation of the confirmed Stammerer is another case in point; here we have a deficiency in the power of the Will over the Muscles, at first displayed only in regard to those of Voice; but when

* The Author has a case at present under his observation, in which not merely the face, but the body and limbs, are thrown into the most extraordinary contortions, upon any agitation of the feelings, however trifling. This gentleman, a man of education and intelligence, of extreme benevolence of character, and a mind habitually well-regulated, can scarcely walk the streets without being liable to the induction of paroxysms of this kind, by causes that could scarcely have been supposed capable of thus operating. For example, he was one day seized by one of these attacks, in consequence of seeing a man miss his footing (as he thought) in descending from the top of an omnibus; and the pleasurable excitement of meeting a friend usually induces the same result. The tendency varies very considerably in its degree, according to the general condition of his health.

feelings of discomfort have been aroused by the failure of attempts to articulate, this want of voluntary control extends itself to the muscular system in general, which is thrown into a sort of paroxysmal effort, that usually subsides only with the explosion of the desiderated sound.

799. The influence of Emotional excitement may operate upon the muscles, however, not only in giving rise to movements which can be attributed to no other source, but also in affecting the power of the Will over the muscular system, by intensifying or weakening its action. For there can be no doubt that, under the strong influence of one class of feelings, the Will can effect results such as the individual would scarcely even attempt in his calmer moments; whilst the influence of another class of feelings is exercised in precisely the opposite direction, weakening or even paralysing the force which was previously in full activity. But the same emotion does not always act in the same mode; thus, the fear of danger may nerve one man to the most daring and vigorous efforts to avert it, whilst another is rendered powerless, and gives way to unavailing lamentations; and the ardent anticipation of success may so unsettle the determinative energy of one aspirant, as to prevent him from attaining his object, whilst another may only be sustained by it in the toilsome struggle of which it is the final reward. Now in order that this variety may be explained, and the *modus operandi* of the Emotions on strictly Volitional* actions may be duly comprehended, we must here state two of the essential conditions of the latter; one of which is, that there should be not merely a distinct conception of the purpose *to be* attained, but also a belief that the purpose *will* or at least *may* be attained; whilst the other is, that the mental energy should be to a great extent withdrawn from other objects, and should be concentrated upon that towards which the Will is directed.—It is within the experience of every one, that there is nothing which tends so much to the success of a volitional effort, as a *confident expectation* of its success; whilst nothing is so likely to induce failure, as the apprehension of it. Now, in so far as regards this mode of their operation alone, the tendency of the cheerful or joyous emotions being to suggest and keep alive the favourable anticipations, whilst that of the depressing emotions (of almost any kind) is to bring before the view all the chances of failure, the former will increase the power of the volitional effort, and the latter will diminish it. And they exert also a direct influence on the physical powers, through the organs of circulation and respiration; the heart's impulses being more vigorous and regular, and the aeration of the blood being more effectually performed, in the former condition than in the latter.—But an altogether contrary effect may be produced by the operation of these two classes of emotions through the second of the above channels. For the more completely the mental energy can be brought into one focus, and all distracting objects

* The term *volitional* was some years since suggested by Dr. Symonds, in an excellent essay on the 'Connection between Mind and Muscle,' published in the "West of England Journal," 1835, as expressing more emphatically than *voluntary* the characters of an action proceeding from a distinct choice of the object, and from a determinative effort to attain it. The word *voluntary* may perhaps be applied to that wider class of actions, in which there is no very distinct choice or conscious effort, but in which the movement flows as it were spontaneously from the antecedent mental state; the consciousness, however, being fully awake to its performance, and the will being brought to bear determinately upon it, whenever an opposing motive tends to check the process or to alter its direction. See § 817.

excluded, the more powerful will be the volitional effort; and the effect of emotional excitement will thus in great degree depend upon the intellectual constitution which the individual may happen to possess. For if he have a considerable power of abstraction and concentration, and a full conviction that he has selected the best or the only means to accomplish his end, the intensest fear of the consequences of failure will only increase the force of the motive which prompts the effort; and the whole energy of which his nature is capable, will display itself in the attempt. In a man of this temperament, the most joyous anticipation of success will produce no abatement of his efforts, no distraction of his attention; but will rather tend to keep him steady to his purpose, until it shall have been accomplished; and then only does he dare to abandon himself to the current of ideas which rolls-in upon his consciousness, so soon as his attention is free to entertain them. But the mind which is deficient in the power of concentrativeness, is lamentably deranged by any kind of emotional excitement in the performance of any voluntary effort. For the fear of failure is constantly suggesting to him new distresses, weakens his confidence in any method suggested for his action, and makes him direct his attention, not to some fixed plan as the best or the only feasible one, but to any and every means that may present a chance of success, or may even serve to avert his thoughts from the dreaded catastrophe; whilst, on the other hand, the joyous anticipation of success leads him to allow his thoughts to direct themselves towards all its agreeable consequences, instead of fixing his intellectual and volitional energy upon the means by which success is to be attained.

800. If this be the true solution of the mode in which the Emotions chiefly affect the exercise of our Volitional powers, we should expect that similar effects might be induced, without any Emotional excitement, by means which affect the Intellectual consciousness alone; and that thus an action otherwise impossible to the individual may be performed by him, if (1) his mind be possessed with a full assurance of success, and (2) his entire motor energy be concentrated in the single exertion; whilst, on the other hand, an action which can be ordinarily performed with the greatest facility may become absolutely impossible to him, if (1) his mind be entirely possessed with the idea of its impossibility, or even (2) if, while his judgment entertains doubts of success, his attention be distracted by a variety of objects, so that he cannot bring it to bear upon the one effort which may alone be needed.—Now experience shows that such is really the case; but as this experience is the most remarkable in regard to certain states of the mind in which these two modes of operation may be worked in combination, it will be sufficient to refer to them for the demonstration (§ § 822, 825). And, having now sufficiently considered the physiological conditions of the purely *Emotional* actions,—which, in regard alike to the state of consciousness wherein they originate, and to the share which the Sensorial centres have in generating that state, may be considered as most nearly allied to the Consensual,—we pass-on to those Psychical operations, of which the Cerebrum must be regarded as the exclusive instrument.

801. Though it is now universally admitted among Psychologists that the mind does not come into existence with thoughts ready formed, or 'innate ideas,' yet there are few who will deny that we are born with such

*tendencies to thought*, that, when these are called into activity, certain results are sure to follow; and further, that whilst there is a certain fundamental similarity in these tendencies to thought, among all minds of ordinary constitution,—so that, when excited to action in the same manner, the same results shall be evolved,—yet that there is such a diversity in the relative degree of these tendencies in different individuals, as of itself becomes a source of different habits of thought. But the habits of thought are also determined in great degree by the influence of the emotions; for, whilst we are disposed to give ourselves up to the contemplation of subjects with which pleasurable feelings are connected, we are equally prone to withdraw our attention from those that are accompanied with feelings of pain or discomfort; and as the relative intensity of the different Emotional states varies greatly among different individuals, it becomes, as already noticed (§ 796), a source of extreme diversity in the formation of all those conclusions by which the conduct of life is directed, and tends to establish certain *uniformities of mental action for each individual*, which constitute what is termed his 'character.' But further, we are not to look merely at congenital peculiarities of psychical constitution, as the source of *original habitudes of thought;* for as the external conditions in which every individual is placed, differ to a certain extent from those which affect each one of his fellows, so does it happen that, as the development of every kind of capacity for mental action is augmented (like the nutrition of muscle and nerve) by its habitual exercise, the strength of that capacity, and its tendency to exert an active influence on the course of thought, will partly depend upon the degree in which circumstances call it into play, especially during the period when, in the natural progress of psychical evolution, it is first taking a prominent share in the operations of the mind. Hence there is a set of *acquired habitudes of thought*, which, no less than those dependent upon original constitution, determine the consequences of any particular impression upon the 'ideational consciousness;' and which thus form part of the 'character' of each individual, at any one period of his existence. But the psychical tendencies of every one undergo a consecutive change in the progress of life. Infancy, Childhood, Youth, Adolescence, Adult age, the period of Decline, and Senility, have all their characteristic phases of psychical as of physical development and decline; and this is shown, not merely in the general advance of the intellectual powers up to the period of middle life, and in their subsequent decay, but in a gradual change in the balance of the springs of action which are furnished by the emotional states, the pleasures and pains of each period being (to a certain extent) of a different order from those of every other. This diversity may be partly attributed to changes in the physical constitution; thus, the sexual feeling which has a most powerful influence on the direction of the thoughts in adolescence, adult age, and middle life, has comparatively little effect at the earlier and later periods. So, again, the thirst for novelty, and the pleasure in mental activity, which so remarkably characterize the young, when contrasted with the obtuseness to new impressions and the pleasure in tranquil occupations which mark the decline of life, may perhaps be attributed, in part at least, to the greater activity of the changes, both of disintegration and reparation, of which the nervous system (in common with the rest of the organized fabric) is the subject

during the earlier part of life, and to its diminished activity as years advance. But there are other changes, which cannot be so distinctly traced to any physical source, but which yet are sufficiently constant in their occurrence, to justify their being regarded as a part of the developmental history of the psychical nature; so that each of the 'Seven Ages of Man' has its own character, which may be with difficulty defined in words, but which is recognized by the apprehension, as it forces itself upon the experience, of every one.

802. It is universally admitted that, notwithstanding all the obvious diversities of Human character and Mental action, there are certain fundamental *uniformities* which may be traced throughout the whole of this series; and it is on the basis afforded by these, that the Science of Psychology is erected, to which may be applied, with a mere alteration of form, the definition given of Physiology in the first page of this treatise:—"The object of the science of *Psychology* is to bring together, in a systematic form, the phenomena which normally present themselves during the existence of *thinking minds;* and to classify and compare these in such a manner, as to deduce from them those general Laws or Principles which express the conditions of their occurrence, and to determine the causes to which they are attributable." As our present object, however, is not to investigate the operations of the Mind itself, but only to consider their relations to those of the bodily Organism, we shall here enter into the examination of the nature and laws of psychical phenomena, only so far as may be requisite for the due explanation of those bodily changes which are related to them.—Of the nature of the connection between Nervous action and Mental action, we can form no distinct idea. Few Physiologists would be disposed to deny that the Cerebrum is the instrument of Psychical powers; and yet no one has been able to form a self-consistent theory of the mode in which it is so. Some, who have attended exclusively to the close relationship which indubitably exists between corporeal and mental states, have thought that *all* the operations of the Mind are but expressions or manifestations of material changes in the Brain; that thus Man is but a thinking machine, his conduct being entirely determined by his original constitution, modified by subsequent conditions over which he has no control, and his fancied power of self-direction being altogether a delusion; and that notions of 'duty' or 'responsibility' have no real foundation, Man's character being formed *for* him and not *by* him, and his mode of action in each individual case being simply the consequence of the reaction of his Cerebrum upon the circumstances which called it into play.* On this view, what is commonly termed Criminality is but one form of Insanity, and ought to be

* For the latest and most thorough-going expression of this doctrine, see the "Letters on the Laws of Man's Nature and Development," by Henry G. Atkinson and Harriet Martineau.—A few extracts will suffice to show the bearings of this system of philosophy. "Instinct, passion, thought, &c. are effects of organized substances." "All causes are material causes." "In material conditions I find the origin of all religions, all philosophies, all opinions, all virtues, and 'spiritual conditions and influences,' in the same manner that I find the origin of all diseases and of all insanities in material conditions and causes." "I am what I am; a creature of necessity; I claim neither merit nor demerit." "I feel that I am as completely the result of my nature, and impelled to do what I do, as the needle to point to the north, or the puppet to move according as the string is pulled." "I cannot alter my will, or be other than what I am, and cannot deserve either reward or punishment."

treated as such; Insanity itself is nothing else than a disordered action of the Brain; and the highest elevation of Man's Psychical nature is to be attained by due attention to all the conditions which favour his physical development. But again, there are others who have limited themselves to the cognizance of Mental phenomena, and who maintain the very opposite doctrine in regard to their nature and source. To them the Mind appears in the light of a separate immaterial existence, mysteriously connected, indeed, with a bodily instrument, but not dependent upon this in any other way for the conditions of its operation, than as deriving its knowledge of external things through its agency, and as making use of it to execute its determinations, so far as these relate to material objects. On this hypothesis, the operations of the Mind itself, having no relation whatever to those of Matter, are never themselves affected by conditions of the corporeal organism, whose irregularities or defects of activity only pervert or obscure the outward manifestations of the Mind, just as the light of the brightest lamp may be dimmed or distorted by passing through a bad medium; and, further, as the Mind is thus independent of its material tenement, and of the circumstances in which this may chance to be placed, but is endowed with a complete power of self-government, it is responsible for all its actions, which must be judged-of by certain fixed standards. Those who most fully and legitimately carry-out this doctrine, are ready to maintain that even in the state of Intoxication, there is no truly mental perversion, and that, in spite of appearances, the *mind* of the Lunatic (*divinæ particula auræ*) is perfectly sound, its bodily instrument being alone disordered.

803. Now the first of these doctrines, legitimately designated the *Materialist*, recognizes certain great facts, on which the Physiologist can scarcely entertain a doubt, notwithstanding the denial of their validity by those who have had comparatively little opportunity of observing them; we refer to the influence of the Body upon the Mind, of physical upon psychical states; an influence which no one will fail to recognize, who studies its phenomena with freedom from preconceived theory. But in reducing the Thinking Man to the level of "a puppet that moves according as it strings are pulled," it is so utterly antagonistic to our own consciousness of possessing a self-determining power,—whilst, in putting aside, as mere delusions, what we feel to be the noblest conceptions of our nature, it is so thoroughly repugnant to the almost intuitive convictions which we draw from the simplest application of our Intelligence to our own Moral Sense,—that we *feel* its essential fallacies with a certainty that renders logical proof quite irrelevant.—On the other hand, the purely *Spiritualist* doctrine is no less encumbered with difficulties, nor less opposed to facts of most familiar occurrence. For whilst it fully recognizes all that the other ignores, it ignores all that it recognizes; and in placing the Mind *outside* of the Body (so to speak), and in denying that the action of the Mind is ever disordered by corporeal conditions, it places us in the dilemma of either rejecting the plainest evidence, or of admitting that, after all, we know nothing whatever about the Mind itself, all that we *do* know being that lower part of our mental nature which operates on the body and is in its turn affected through it. For it must be admitted that, in the delirious ravings of Intoxication or of Fever, or in the perverted reasoning of the Lunatic, we have the same evidence

f *mental* operation, that we have in the sayings and doings of the same ıdividuals in a state of sanity; and ample testimony to this effect is orne by those, who have observed their own mental state during the ccess of these conditions, and who have described the alteration which akes place in the course of their thoughts, when as yet neither the ensorial nor the motor apparatus was in the least perturbed.* Nothing an be more plain to the unprejudiced observer, than that the introduc-ion of Alcohol, or Opium, or other intoxicating agents, into the circu-lating system, perverts the action of the *mind*, disordering the usual sequence of phenomena most purely psychical, and occasioning new and strange results which are altogether diverse from those of its normal ope-ration. And when once this influence of physical conditions upon mental phenomena has been admitted, we can scarcely refrain from attributing to it a very wide range of action; seeing as we do how very much the due balance of the Emotions is dependent upon the purity of the blood and the general vigour of the system, and how strangely the normal succession of Intellectual operations may be interrupted or altered by local affections of the Cerebrum. No Physiologist could venture to deny, in the face of the crowd of facts which force themselves on his attention, that all Mental phenomena are inextricably linked with Vital changes in the Nervous system; and that the regular performance of the latter (which we have seen to be dependent on the due combination of physical and dynamical conditions) is essential to the normal sequence of the former. Nor can any one who duly examines the evidence which has been collected on the subject of Idiocy and Cretinism, feel any doubt that, in the original development of the Mental powers, the healthful activity of the Corporeal organism has just as important a share, as it has in their subsequent maintenance.

804. It may be fairly asked, then, whether there be any mode of combining the truths contained in the Materialist and Spiritualist doctrines, and of separating them from their associated errors; and whether any general expression can be framed, which may be in harmony alike with the results of scientific inquiry into objective facts, and with those simple teachings of our own consciousness, which must, after all, be recognized as affording the ultimate test of the truth of all Psychological doctrines. The Author is not without hope that some approach to such a solution may be found in the views of which the following is an outline; and although far from regarding them as expressing the *whole* truth, or as solving *all* the difficulties of the subject, he considers that they express so much *more* than any scheme he has ever heard of, that he ventures to request for them a thoughtful consideration on the part of those who feel, with him, the importance of attaining some definite conceptions on this head.—In the first place it may be remarked, that the whole tendency of Philosophical Investigation at the present day is to show the utter futility of all the controversies which have been carried on with regard to the relation of *Mind* and *Matter*. The essential nature of these two entities is such, that no relation whatever *can* exist between them. Matter possesses extension, or occupies space; whilst Mind has

* See especially the work of M. Moreau "Du Hachisch et de l'Aliénation Mentale, Etudes Psychologiques," Paris, 1845; and the well-known "Confessions of an English Opium-Eater."

no such property. On the other hand, we are cognizant of Matter only through its occupation of space, of which we are informed through our senses; we are cognizant of the existence of Mind by our direct consciousness of feelings and ideas, which are to us the most certain of all realities. But, what is perhaps a more important distinction, the existence of Matter is essentially *passive;* left to itself, it always impresses our consciousness in one and the same mode; and any change in its condition is the consequence of external agency. What have been termed the active states of matter, are really the manifestations of *forces,* of which we can conceive as having an existence independent of matter, and as having no other relation to it than that which consists in their capability of changing its state. Thus Water continues unchanged so long as its temperature remains the same; but the dynamical agency of Heat occasions that mutual repulsion between its particles, which transforms it from a non-elastic liquid into an elastic vapour; and all that heat is given forth from it again, when the aqueous vapour is transformed back to the liquid state. On the other hand, the existence of Mind is essentially *active;* all its states are states of change, and we know nothing whatever of it save by its changes. Sensations, Perceptions, Ideas, Emotions, Reasoning processes, &c., in fact every term which expresses a Mental state, is a designation of a phase of mental existence which intervenes between other phases, in the *continual succession* of which our idea of Mind consists.

805. But whilst between Matter and Mind it is utterly vain to attempt to establish a relation of identity or analogy, a very close relation may be shown to exist between *Mind* and *Force.* For, in the first place, Force, like Mind, can be conceived-of only as in a state of activity; and our idea of it essentially consists in the succession of different states, under which its manifestations present themselves to our consciousness. But, secondly, our consciousness of Force is almost as direct, as is that of our own mental states; our notion of it being based upon our internal sense of the exertion which we determinately make to develope one form of Force, which may be taken as the type of all the rest,—that, namely, which produces or which resists motion. When we attempt to lift a weight, or to put a windlass in motion, or to stop a horse that is running away, we are directly conscious of a mental exertion, as the immediate and invariable antecedent of the development of motor power through the contraction of our muscles; and the connection of the two is further established by that 'sense of effort' which we intuitively refer to the muscles themselves, arising as it does from their own condition (§ 754); and thus we are led to feel that, in this particular case, Force must be regarded as the direct expression or manifestation of that Mental state which we call Will. The analogy becomes stronger, when we trace it into the relations which these two agencies respectively bear to Matter. For in the phenomenon of Voluntary movement, we can scarcely avoid seeing that Mind is *one* of the dynamical agencies which is capable of acting-on Matter; and that, like other such agencies, the mode of its manifestation is affected by the nature of the material *substratum* through which its influence is exerted. Thus, the Physiologist knows full well, that the immediate operation of the Will is not upon the Muscle but upon the Brain, wherein it excites that active state of Nervous matter, which he

designates as the operation of Nerve-force; and that the propagation of this force along the Nerve-trunks is the determining cause of the Muscular contraction, which is the immediate source of the motor power. He knows, too, that this dynamical metamorphosis is effected (like every other analogous change) by the intermediation of a peculiar material *substratum*, which itself undergoes a change of condition; the components both of the Nervous and Muscular substances, ceasing to exist under their previous forms, and entering into new combinations. — Thus, then, we have evidence, in what we know of the physiological conditions under which Mind produces Motion, that certain forms of Vital Force constitute the connecting link between the two; and it is difficult to see that the dynamical agency which we term Will is more removed from Nerve-force, on the one hand, than Nerve-force is removed from Motor force on the other. Each, in giving origin to the next, is itself expended, or ceases to exist *as such;* and each bears, in its own intensity, a precise relation to that of its antecedent and its consequent.—But we have not only evidence of the excitement of Nerve-force by Mental agency; the converse is equally true, Mental activity being excited by Nerve-force. For this is the case in every act in which our Consciousness is excited through the instrumentality of the Sensorium, whether its condition be affected by impressions made upon Organs of Sense, or by changes in the state of the Cerebrum itself; a certain active condition of the nervous matter of the Sensorium, being (we have every reason to believe) the immediate antecedent of *all* consciousness, whether sensational or ideational. And thus we are led to perceive, that, as the power of the Will can develope Nervous activity, and as Nerve-force can develope Mental activity, there must be a *Correlation* between these two modes of dynamical agency, which is not less intimate and complete than that which exists between Nerve-force on the one hand, and Electricity or Heat on the other (§ 365). This idea of Correlation of Forces will be found completely to harmonize with those phenomena already referred-to, which unmistakeably indicate the influence of physical conditions in the determination of mental states (§ 803); whilst, on the other hand, it explains that relation between Emotional excitement and bodily change, which is manifested in the subsidence of the former, when it has expended itself in the production of the latter (§ 797). And further, it will be found no less applicable to the explanation of all that *automatic* action of the Mind, which consists in the succession of ideas, according to certain 'laws of thought,' without the exercise of any control or direction on the part of the individual to whose consciousness they present themselves, and which manifests itself in the action of those ideas upon the centres of movement. For this succession must be regarded as the exponent of a series of changes taking place in the Cerebrum itself, in respondence to impressions made upon it; whilst the motions which proceed from these must be considered as being no less the results of its 'reflex' operation, than are the 'consensual' of the reflex action of the Sensory Ganglia, and the 'excito-motor' of that of the Spinal Cord.* For all Physiological purposes, then,

* The application of the doctrine of 'reflex action' to the Brain, was first fully developed by Dr. Laycock of York, in a paper 'On the Reflex Function of the Brain,' read before the Medical Section of the British Association at its meeting in York, Sept., 1844, and after-

we may consider the nervous matter of the Cerebrum as the *material substratum* through which the metamorphosis of Nerve-force into Mind-force, and of Mind-force into Nerve-force, is effected; and as every such metamorphosis involves, like other analogous transformations, a change in the state of the matter through which it is effected, so should we expect that Mental activity would involve the disintegration of the Nervous substance which thus ministers to it; and such appears (§§ 358–362), from a variety of evidence, to be really the case.

806. It is obvious that the view here taken does not in the least militate against the idea, that Mind may have an existence altogether independent of the Material body through which it here manifests itself. All which has been contended for is, that the connection between the Mind and Body is such, that each has, in virtue of its constitution, a determinate relation to the other, in this present state of existence (which is all of which Science can legitimately take cognizance); and that the actions of our Minds, *in so far as they are carried-on without any interference from our Will*, may be considered (in the limited sense formerly explained, § 395) as functions of the Cerebrum. — On the other hand, in the control and direction which the Will has the power of exerting over the course of the thoughts, we have the evidence of a new and independent power, which is entirely opposed in its very nature to all the automatic tendencies, and which, according as it is habitually exerted, tends to render the individual *a free agent*. And, truly, in the existence of this Power, which is capable of dominating over the very highest of those operations that we know-of as connected with corporeal states, we find a better evidence than we gain from the study of any other part of our psychical nature, that *there is* an entity, wherein Man's nobility essentially consists, which does not depend for its existence on any play of physical or vital forces, but makes these subservient to its determinations. It is, in fact, in virtue of the Will, that we are *not* mere thinking automata, mere puppets to be pulled by suggesting-strings, capable of being played-upon by every one who shall have made himself master of our springs of action. It may be freely admitted that such thinking automata *do* exist: for there are many individuals whose Will has never been called into due exercise, and who gradually almost entirely lose the power of exerting it, becoming the mere creatures of habit and impulse; and there are others in whom (as we shall hereafter see) such states are of occasional occurrence; whilst in others, again, they may be artificially induced. And it is by the study of those states in which the Will is completely in abeyance,—the course of thought being *entirely* determined by the influence of suggestions upon the Mind, whose mode of reaction upon them depends upon its original peculiarities and subse-

wards published in the "Brit. and For. Med. Rev.," vol. xix.—Not having recognised what appears to the Author the essential distinction, both in their anatomical and physiological relations, between the Sensory Ganglia and the Cerebrum or Hemispheric Ganglia, Dr. Laycock did not mark-out the distinction between the '*sensori*-motor' or 'consensual' actions, which are the manifestations of the reflex power of the former, and the '*ideo*-motor' actions which depend upon the reflex action of the latter. But in adopting that part of it which is strictly applicable to the Cerebrum, and in applying it to those various states which agree in the common characteristic of the existence of Mental Activity without Volitional control, the Author considers that he is merely giving greater definiteness and a wider application to Dr. Laycock's doctrine.

quently-acquired habits,—and by the comparison of such states with that in which an individual, in full possession of all his faculties, and accustomed to the habitual control and direction of his thoughts, determinately applies his judgment to the formation of a decision between various plans of action, involving the appreciation of opposing motives,—that we shall obtain the most satisfactory ideas of what share the Will really takes in the operations of our minds and in the direction of our conduct, and of what must be set down to the Automatic operation of our psychical nature.

807. We shall now briefly pass in review the chief of those modes of Psychical activity, which constitute in the aggregate what we are accustomed to term the Intellectual Powers. And the first of these in order of development, and that which lies at the foundation of all the rest, is the *Association of Ideas*, that is, the formation of such a connexion between two or more ideas, that the consciousness of one tends to bring the other also before the consciousness; or, in other words, each tends to *suggest* the other. Certain laws of Association, expressive of the conditions under which this connection is formed, and the mode in which it acts, have been laid down by Psychologists; and these may be concisely stated as follows:—1. *Law of Contiguity.* Two or more states of consciousness, habitually existing together or in immediate succession, tend to cohere, so that the future occurrence of any one of them is sufficient to restore or revive the other. It is thus (to take a simple illustration) that the impressions made upon our sensational consciousness by natural objects, which are usually received through two or more senses at once, are compacted into those aggregate notions, which, however simple they may appear, are really the result of the intimate combination of many distinct states of ideation. Thus our notion of the *form* of an object is made up of separate notions derived from the visual and muscular senses respectively; our notion of the character of its surface, from the combination of impressions received through the visual and tactile senses; and with both of these our notion of colour, as in the case of an orange, may be so blended, that we do not readily conceive of its characteristic form and surface, without also having before our minds the hue with which these have been always associated in our experience. So, again, the external aspect of a body suggests to our minds its internal arrangement and qualities, such as we have before found them invariably to be; thus, to use the preceding illustration, the shape and colour of the orange bring before our consciousness its fragrant odour and agreeable taste, as well as the internal structure of the fruit. And our notion of an orange must be considered as the aggregate of all the preceding ideas.—Not only the different ideas excited by one object, but those called-up by objects entirely dissimilar, may thus come to be associated, provided that the mind has been accustomed to the presentation of them in frequent contiguity one with the other. Such conjunctions may be natural, that is, they may arise out of the 'order of nature;' or they may be artificial, being due to human arrangements; all that is requisite is, that they should have sufficient permanence and constancy to habituate our minds to the association.—Of this law of contiguity, moreover, we have a most important example in the association which the mind early learns to form between successive *events*, so that when the first has been followed

by the second a sufficient number of times to form the association, the occurrence of the first suggests the *idea* of the second; if that idea be verified by its occurrence, a definite *expectation* is formed; and if that expectation be unfailingly realized, the idea acquires the strength of a *belief.* And thus it is that we come to acquire that part of the notion of 'cause and effect,' which consists in invariable and necessary sequence (see p. 3), and to form our fundamental conception of the invariability of Nature. It is by the same kind of operation, again, that we come to employ words as the symbols of ideas, for the convenience of intercommunication and reference (§ 790); a certain number of repetitions of the sound, concurrently with the sight of the object, or the suggestion of the notion of that object, being sufficient to establish the required relation in our minds. Of the large share which this kind of action takes in the operations of *Memory* and *Recollection*, evidence will be presently given. —The readiness with which these Associations are formed, varies greatly in different individuals and at different periods of life. As a general rule, it is far greater during the period of growth and development, than after the system has come to its full maturity; and remembering that those new functional relations between other parts of the Nervous system, which give rise to the 'secondarily-automatic' movements or acquired instincts, are formed during the same period, it seems fair to surmise that the substance of the Cerebrum *grows-to* the conditions under which it is habitually exercised; and as its subsequent nutrition (according to the general laws of assimilation, § 591) takes place on the same plan, we can understand the well-known force of early associations, and the obstinate persistence of early habits of thought.

808. But a not less important 'tendency to thought,' and one whose operation is more concerned in all the higher exercises of our reasoning faculties, is that which may be expressed under the designation of the *Law of Similarity*, and which consists in the general fact that any present state of consciousness tends to revive previous states that are similar to it. It is thus that we instinctively invest a new object with the attributes we have come to recognize in one that we have previously examined, to which the new object bears such a resemblance, that the sight of the latter suggests those ideas which our minds connect with the former. Thus, we will suppose a man to have once seen and eaten an orange; when he sees an orange a second time, although it may be somewhat larger or smaller, somewhat rougher or smoother, somewhat lighter or darker in hue, he recognizes it as an orange, and mentally assigns to it the fragrance and sweetish acidity of the one which he had previously eaten. But if, instead of being yellow, the fruit were green, he would doubt of its being an orange; and if assured that it still was, but had not come to maturity, he would no longer expect to find it sweet, the notion of intense acidity being suggested to his mind by his previous experience of other green and unripe fruit.—It is in virtue of this kind of action, that we extend those elementary notions which are primarily excited by sensation, to new objects. Thus, the idea of roundness (like other notions of form) is originally based on the combination of the muscular and visual sensations, and must be first acquired by a process of considerable complexity; but when once derived from the examination of a single object, it is readily extended to other objects of the same charac-

ter.—So, again, it is by the operation of this mental tendency, that we recognize similarity where it exists in the midst of difference, and separate the points of agreement from those of discordance; and this, again, not merely as regards objects which are before our consciousness at the same time or in close succession, but also with regard to all past states of consciousness. It is thus that we *identify* and *compare*, that we lay the foundations of classification, and that we recover all past impressions which have anything in common with our present state of consciousness. The intensity of this tendency, and the habitual direction which it takes, vary extremely in different individuals. Some have so great an incapacity for recognizing similarity, that they can only perceive it when it is in marked prominence, their minds taking much stronger note of differences; whilst others have a strong bias for the detection of resemblances and analogies, and discover them where ordinary minds cannot recognize them. Some, again, address themselves to the discovery of similarity among objects of sense, whilst others study only those ideas which are the objects of our internal consciousness; and it is in the detection of what is essentially similar among the latter, that all the higher operations of the intellect essentially consist. Even here we find that some are contented with superficial analogies, whilst others are not satisfied until they have penetrated by analysis to the depths of the subjeet, and are able to compare its fundamental idea with others of like kind.—It is this habit of mind, which is of essential value in all the sciences of Classification and Induction. Thus, in the formation of generic definitions to include the characters which a number of objects have in common, their subordinate differences being for a time left out of view, we are entirely guided by the recognition of similarity between the objects we are arranging; and the same is the case in the formation of all the higher groups of families, orders, and classes, the points of similarity becoming fewer and fewer as we proceed to the more comprehensive groups, whilst those of difference increase in corresponding proportion. The sagacity of the Naturalist is shown in the selection of the *best* points of resemblance, as the foundation of his classification; the value of characters being determined, on the one hand by their constancy, and on the other by their degree of coincidence with important features of general organization or of physiological history.* In the determination of Physical laws, the process is somewhat of the same kind; but the similarities with which we have here to do, are not, as in the preceding case, objective resemblances, but exist only among our subjective ideas of the nature and causes of the phenomena brought under our consideration. Thus, there is no obvious relation between the fall of a stone to the Earth, and the motion of the Moon in an elliptical orbit around it; but the penetrating mind of Newton detected a relation of *common causation* between these two phenomena, which enabled him to express them both under one law. It was by a like intellectual perception of similarity, that Franklin was led to determine the identity of lightning with the spark from an electrical machine. And it would be easy to show that it has

* Thus, for example, it is now generally admitted, amongst Zoologists, that the Implacental Mammalia should constitute a separate sub-class, in virtue of the peculiar conformation of their generative apparatus, instead of being distributed among other Orders, as they were left by Cuvier.

been in their extraordinary development of this power of recognizing *causative* similarity, leading to a kind of intuitive perception of its existence where no adequate ground can be assigned by the reason for such a relationship, that those men have been eminent, who have done the most to advance science by the process of inductive generalization.—The same kind of mental action is also employed in the contrary direction; namely, in that extension of generic definitions to new objects, which takes place upon every discovery of a new species; and in that application of general laws to particular instances, which constitutes deductive reasoning. We may trace it again, even in the extension of the meaning of words so as to become applicable to new orders of ideas, in consequence of the resemblance which the latter are felt to bear to those of which the words were previously the symbols: as in the application of the word 'head,' which primarily designated the most elevated part of the human body, in such phrases as the 'head of a house,' the 'head of a state,' the 'head of an army,' the 'head of a mob,' in each of which the idea of superiority and command is involved; or in the phrases the 'heads of a discourse,' or the 'heads of an argument,' in which we still trace the idea of authority or direction; or in the phrases the 'head of a table,' the 'head of a river,' in which the idea of superiority or origin comes to be locally applied; or in the 'head of a bed,' or 'head of a coffin,' in which we have the more distinct local association with the position of the head of man. Of the foregoing applications, those first cited belong to the nature of a metaphor, which has been described to be "a simile comprised in a word;" and the judicious use of metaphors, which frequently adds force as well as ornamental variety to the diction, is most seen amongst men who possess a great power of bringing together the 'like' in the midst of the 'unlike.'—Every effort, in fact, to trace-out unity, consistency, and harmony, in the midst of the wonderful and (at first sight) perplexing variety of objects and phenomena amidst which we are placed, is a manifestation of this tendency of the Human Mind; and, when conducted in accordance with the highest teachings of the Intellect, or guided by that Intuition which in some minds supersedes and anticipates all reasoning, it enables us to rise towards the comprehension of that great Idea of the Universe, which we believe to exist in the Divine Mind in a majestic simplicity of which we can here but faintly conceive, and of which all the phenomena of Nature are but the manifestations to our consciousness.—It may be remarked that this mode of action of the mind is in some degree opposed to the preceding; for whilst *contiguity* leads to the arranging of ideas as they happen to present themselves in natural juxtaposition, and thus to induce a routine which is often most unmeaning (§ 836), *similarity* breaks through juxtaposition, and brings together like objects from all quarters. And it is further to be observed, that, with this purely intellectual operation, there is frequently associated a peculiar feeling of pleasure, which constitutes a true emotional state. All the discoveries of identification, where use and wont are suddenly broken through, and a common feature is made known among objects previously looked-on as entirely different, produce a flash of agreeable surprise, and the kind of sparkling cheerfulness that arises from the sudden lightening of a burden. There are few who devote themselves to the pursuit of Science, who do not experience this pleasure, either from the detection of new relations of similarity by

their own perception of them, or in the recognition of them as developed by others. It is, however, much more intense in some minds than in others; and according to its intensity, will it act as a motive in the prosecution of scientific inquiry amidst discouragements and difficulties. It is recorded of Newton, that when he was bringing his great idea of the causative relation between terrestrial gravity and the motions of the heavenly bodies, to the test of calculation, his agitation became so great, that he could not complete the computation and was obliged to request a friend to do so.

809. Although the single relations established between ideas, either through contiguity or through similarity, may suffice for their mutual connection, yet that connection becomes much stronger when two or more such relations exist consentaneously. Thus, if there be present to our minds two states of consciousness, each of them associated, either by contiguity or similarity, with some third state that is past and 'out of mind' at the time, the compound action is more effective than either action would be separately; that is, the separate suggestions might be too weak to revive the past state of consciousness, but reproduce it by acting together. Of this, which has been termed the *Law of Compound Association*, we have examples continually occurring to us in the phenomena of Memory; but it is especially brought into operation in the voluntary act of Recollection (§ 813).—Another mode in which the associative tendency operates, is in the formation of aggregate conceptions of things that have never been brought before our consciousness by sensory impressions. This faculty, which has been termed that of *Constructive Association*, is the foundation of Imagination; and it is exercised in every other mental operation in which we pass from the known to the unknown. When we attempt to form a conception, which shall differ from one that we have already experienced as a matter of objective reality, by the introduction of only a single new element,—as when we imagine a brick building replaced by one of stone in every respect similar as to size and form,—we substitute in our minds the idea of stone for that of brick, and associate it by the principle of contiguity with those other ideas, of which that of the whole building is an aggregate. So, again, if we conceive a known building transferred from its actual site to some other already known to us, we dissociate the existing combinations, and keep together the ideas which were previously separated, until their contiguity has so intimately united them, that the picture of the supposed combination may present itself to the mind exactly as if it had been a real scene which we had long and familiarly known. By a further extension of the same power, we may conceive the elements to be varied, as well as the mode of their combination; and thus we may bring before our consciousness a representation, in which no particular has ever been before our minds under any similar aspect, and which is, therefore, *as a whole* entirely new to us, notwithstanding that, when we decompose it into its ultimate elements, we shall find that each of these has been previously before our consciousness. Such a representation, by being continually dwelt-on, may come to have all the force and vividness of one derived from an actual sensory impression; and we can scarcely conceive but that the actual state of the Sensorium itself must be the same in both cases, though this state is induced in the one case by an act of Mind, and in the other by Material conditions.

A very common *modus operandi* of this 'constructive association,' is the realization of a landscape, a figure, or a countenance, from a pictorial representation of it. Every picture must be essentially defective in some of the attributes of the original, as, for example, in the representation of the *projection* of objects; and all, therefore, that the picture can do, is to *suggest* to the mind an idea, which it completes for itself by this constructive process, so as to form an aggregate which may or may not bear a resemblance to the original, according to the fidelity of the picture, and the mode in which it acts upon the mind of the individual. Thus to one person a mere sketch shall convey a much more accurate notion of the object represented, than a more finished picture shall give to another; because, from practice in this kind of mental reconstruction, the former recognizes the true meaning of the sketch, and fills it up in his 'mind's eye;' whilst the latter can see little but what is actually before his bodily vision, and interprets as a literal presentation that which was intended merely as a suggestion. And it is now generally admitted, that in all the higher forms of representative Art, the aim should be, *not* to call into exercise the faculty of mere objective *realization*, but to address that higher power of *idealization*, which invests the conception suggested by the representation with attributes more exalted than those actually possessed by the original, yet not inconsistent with them. It depends, however, as much on the mind of the individual addressed, as on that of the Artist himself, whether such conceptions shall be formed; since by those who do not possess this power, the highest work of Art is only appreciated, in so far as it enables them to realize the object which it may represent.

810. Having thus pointed out what may be considered the most elementary forms of Mental Action,* we shall briefly pass in review those more complex operations, which may be regarded as in great part compounded of them. The capacity for performing these is known as the Intellect or the Reasoning Power; and the capacities for those various forms of Intellectual activity, which it is convenient to distinguish for the sake of making ourselves more fully acquainted with them, are termed Intellectual Faculties. It appears to the Author, however, to be a fundamental error to suppose that the entire Intellect can be *split-up* into a certain number of faculties; for each faculty that is distinguished by the Psychologist expresses nothing else than a *mode of activity*, in which the whole power of the Mind may be engaged at once,—just as the whole power of the locomotive steam-engine may be employed in carrying it forwards or backwards, according to the direction given to its action. And if this be true, it must be fundamentally erroneous to attempt to parcel-out the Cerebrum into distinct 'organs' for these respective faculties; the whole of it (so far as we can form a judgment) being called into operation in every kind of mental activity.

811. That state in which the consciousness is actively directed to a Sensorial change,—whether this change originate in impressions received through the external organs of sense, or in operations of the

* In the foregoing brief exposition of the laws and leading phenomena of Mental Association, the Author has derived great aid from the excellent article on 'The Human Mind,' contributed to Messrs. Chambers's "Information for the People," by his friend Mr. Alexander Bain.—Though not agreeing with all the views expressed in that article, the Author can cordially recommend the perusal of it to his readers.

Cerebrum,—is termed *Attention.* Like the other states of Mental Activity, which will come under our consideration, it may be either *voluntary* or *automatic;* that is, we may either 'fix our attention' on an object of consciousness by an effort of the Will, or the attention may be drawn towards it by the attractive qualities of the object itself, and may be held to it until it is intentionally detached, or until the mind has become satisfied by the persistence of one kind of impression. The intentional direction of the attention to external objects, is what is commonly known as *Observation;* those men being designated as 'observant,' who do not allow their attention to be so far engrossed by one object or occurrence, or (as very frequently happens) by their own trains of thought, as to exclude the cognizance of what may be taking place around them; whilst those are spoken-of as 'unobservant,' who, by allowing their consciousness to remain fixed upon some one object or train of thought, prevent it from receiving a legitimate degree of influence from other impressions received and transmitted to the Sensorium by the organs of sense. We shall hereafter (CHAP. XV., Sect. 1) more particularly examine the remarkable influence of Attention in augmenting the acuteness of sensory impressions; but it may be here remarked, that the same influence extends itself to the perception of our own mental states; and that, as will be presently shown (§ 817), it is in the degree of Attention which we automatically or voluntarily bestow on certain ideas presented to us by suggestion, that those peculiar modes of thought, which are sometimes termed Intellectual Faculties, essentially consist.—The intentional direction of the consciousness to what is passing *within* us, is sometimes designated as Reflection, but is more appropriately termed *Introspection.*

812. The reproduction of past states of consciousness by either of the forms of suggestive action already described, constitutes what is known as *Memory.**—There seems much ground for the belief, that *every*

* It is commonly stated that Memory consists in the renewal of past sensations and of the ideas they have excited; but it may be questioned whether we primarily retain anything else than the impressions left by *ideas*, and whether the recall of *sensations* is not a secondary change, dependent upon the reaction of ideational (Cerebral) changes upon the Sensorium. For if we wish to reproduce any sensational state,—whether visual, auditory, olfactive, gustative, or tactile,—we first recall the notion of some object by which that state was formerly produced; and it is only by keeping that notion strongly before our consciousness, that we can bring ourselves to see, hear, smell, taste, or feel, that which we desire to experience. Indeed it is not every one who can thus reproduce sensational states, the general notion being most commonly all that is arrived-at; of this we have a good illustration in the conception we form of the face of an absent friend, it being only a comparatively small number of persons who are able to reproduce the visual image with sufficient distinctness to serve as a model for delineation, although a much larger number would be able to say how far such a delineation realized their own conception of the countenance, and to point out in what it might depart from this. It is a further confirmation of this view, that the *expression* of a countenance, which directly appeals to our ideational consciousness, is much more distinctly remembered by most persons than the *features*, the recognition of which is more dependent upon the recall of antecedent sensational states.—What is true of the act of Recollection in this particular, is probably true also in great degree of *spontaneous* Memory; but perhaps we should admit that the renewal of past states of sensational consciousness may be effected by fresh sensory impressions which are closely allied to them; as would seem probable from the fact, that we find ourselves comparing the new sensations with the old, without having in the mean time formed any distinct conception of the object by which the old were produced.—It may, however, be pretty certainly affirmed that the Sensory Ganglia do not themselves register *sensory impressions;* and that these can only be reproduced afresh by external objects, or by the occurrence of ideational changes in the Cerebrum. On the other hand, the

sensory impression which has been once recognized by the perceptive consciousness, is registered (so to speak) in the Cerebrum, and may be reproduced at some subsequent time, although there may be no consciousness of its existence in the mind during the whole intermediate period. Instances are of very frequent occurrence, in which ideas come up before the mind during delirium or dreaming, and are expressed at the time or are subsequently remembered, although the individual cannot himself retrace them as having ever before been present to his consciousness; they being yet proved to have been so at some long antecedent period. A very extraordinary case of this kind has been recorded, in which a woman, during the delirium of fever, continually repeated sentences in languages unknown to those around her, which were found to be Hebrew and Chaldaic; of these she stated herself, on her recovery, to be perfectly ignorant; but on tracing her former history, it was ascertained that, in early life, she had lived as servant with a clergyman, who had been accustomed to walk up and down his passage, repeating or reading aloud sentences in these languages, which she must have retained in her memory unconsciously to herself.—Of the nature of the change by which sensory impressions are thus registered, it seems in vain to speculate; there can be little question, however, that it is in some way dependent upon the nutrition of the Cerebrum, since we see that alterations in that function have a marked effect upon the Memory. Thus, in the case just cited, we can scarcely doubt that some alteration either in the circulation of the blood through the cortical substance of the Cerebrum, or in the quality of the fluid, was the cause of changes, which, transmitted downwards to the Sensorium, reproduced the former sensations; just as a disturbance of the circulation in the retina produces the sensation of flashes of light or other visual phenomena. Again, it is certain that disease or injury of the Cerebrum may destroy the Memory generally, or may affect it in various remarkable modes. Thus we not unfrequently meet with cases, in which the brain has been weakened by attacks of epilepsy or apoplexy, in such a manner as to prevent the reception of any *new* impressions; so that the patient does not remember anything that passes from day to day; whilst the impressions of events which happened *long before* the commencement of his malady, recur with greater vividness than ever. On the other hand, the memory of the long-since past is sometimes entirely destroyed; whilst that of events which have happened subsequently to the malady, is but little weakened. The memory of particular classes of ideas is frequently destroyed; that of a certain language, or some branch of science, for example. The loss of the memory of words is another very curious form of this disorder, which not unfrequently presents itself: the patient understands perfectly well what is said, but is not able to reply in any other terms than *yes* or *no*—not from any paralysis of the muscles of articulation, but from the incapability of expressing the ideas in language. Sometimes the memory of a particular class of words only, such as nouns or verbs, is destroyed; or it may be impaired merely, so that the patient mistakes the proper terms, and speaks a most curious jargon. So, again, a person may remember the letters of which a word is composed, and

Cerebrum seems to act quite independently of the Sensory Ganglia, in reproducing *ideas;* save in so far as the results of its action must (on the theory here advanced) be impressed on the Sensorium, before we can be rendered conscious of them.

may be able to *spell* his wants, though he cannot speak the *word* itself; asking for *bread* (for example) by the separate letters b, r, e, a, d. A very curious affection of the memory is that in which the *sound* of spoken words does not convey any idea to the mind; yet the individual may recognize in a written or printed list of words, those which have been used by the speaker; and the *sight* of them enables him to understand their meaning. Conversely, the sound of the word may be remembered, and the idea it conveys fully appreciated; but the visual memory of its written form may be altogether lost, although the component letters may be recognized. For this class of phenomena, in which there is rather a severance of the associative connections that have been formed between distinct states of consciousness, than an actual annihilation of the impression left by any of the latter, the term 'dislocation of memory' has been proposed by Dr. Holland;* but, as he justly remarks, "no single term can express the various effects of accident, disease, or decay, upon this faculty, so strangely partial in their aspect, and so abrupt in the changes they undergo, that the attempt to classify them is almost as vain as the research into their cause." It is, perhaps, in the sudden changes produced by blows or falls, that we have the most extraordinary examples of this kind of disturbance; and it is scarcely less extraordinary, that there should sometimes be a no less sudden recovery of the lost impressions, which we can scarcely do wrong in attributing to the return of the Cerebral organization to that previous condition from which it had been perverted.—When we take all these phenomena into consideration, we can scarcely resist the conclusion that every act of perceptive consciousness produces a certain modification in the nutrition of the Cerebrum; that the new mode of nutrition is continued according to the laws of Assimilation already adverted-to; and that thus the Cerebrum forms itself in accordance with the use that is made of it. And this unconscious storing-up of impressions, which can only be brought before the consciousness (under ordinary circumstances at least) by the connecting link of associations, affords a powerful argument for the doctrine which has already been frequently referred-to as probable,—that the Cerebrum is not itself a centre of consciousness, but that we only become conscious of *its* states, in the same manner as we do of those of the Retina and of other surfaces for the reception of external impressions, by means of the communication of the changes which take place in it to the Sensorium.

813. Although the term Memory is very commonly used to designate the *intentional* recall of past states of consciousness, as well as their spontaneous or automatic recurrence, yet it is properly restricted to the latter operation; the term *Recollection* being that which is appropriate to the former, whose peculiarity consists in the exertion of the Will to bring that before the consciousness, which does not spontaneously present itself. Now as this process affords a typical example of the mode in which the Will acts in directing the current of thought, we shall examine it a little more minutely.—In the first place it may be positively affirmed, that we cannot call up any idea by simply *willing* it; for it is a necessary condition of an act of will, that there should be in the mind an idea of *what* is willed; and if the idea of the thing willed be already in the

* See his "Chapters on Mental Physiology," p. 146.

mind, it is obviously impossible to use the will to bring it there. But every one is conscious of the state of mind, in which he *tries to remember* something which is not at the time present to his consciousness; and the question is, *how* he proceeds to bring the idea before his mind. The process really consists in the fixation of the attention upon one or more ideas already present to the mind, which may recall, by suggestion, that which is desiderated; the very act of thus *attending to* a particular idea not only serving to intensify the idea itself, but also to strengthen the associations by which it is connected with others. There are certain ideas so familiar to us, that they seem necessarily to recur upon the slightest prompting of suggestion; yet even with regard to these, the voluntary recollection at any particular time involves the process just described. Thus if a man be asked his name, he usually finds no difficulty in giving the proper answer, because it only requires that his attention should be directed to the idea involved in the words 'my name,' to suggest the words of which that name may consist. But if the individual should be in that state of 'absence of mind,' which really consists in the fixation of the attention upon some internal train of thought, he may not be able on the sudden to transfer his attention to the new idea that is forced upon his consciousness *ab externo;* and may thus hesitate and bungle, before he is able to answer the question with positiveness. So, again, it sometimes happens in old age that men fail to recollect their own names, or the names of persons most familiar to them, in consequence of the weakening of the bond of direct association; and they then only recall it by the operation to be presently described. And there are states of mind, in which the power of voluntarily directing the thoughts is for a time suspended, and in which the individual cannot make the slightest effort to recall the most familiar fact, especially if possessed with the conviction that such effort is impossible (§ 825).—But supposing the mind to be in full possession of its ordinary powers, and the desiderated idea to be one which does not at once recur on the direction of the attention to some idea already in the mind; we then apply the same process to other ideas which successively come before our consciousness, selecting those which we think most likely to suggest that which we require, and following-out one train of thought after another, in the directions which we deem most probable, until we either succeed in finding the idea of which we are in search, or give up the pursuit as not worth further trouble. Thus a man who is making-up his accounts, and finds that he has expended a sum in a mode which he cannot recollect, sets himself to remember what business he has done, where he has recently been, what shops he may have entered, and so on. Or when a man meets another whom he recognizes as an acquaintance without remembering his name, he runs over a number of names (one being suggested by another, when the attention is given to them), in hopes that some one of these may prove to be the one, which, when brought to his mind, is recognized as that of the object then before his consciousness; or he thinks of the place in which he may have previously seen him, this being recalled by fixing the attention on the associations suggested by the sight of his face and figure, or by the sound of his voice, or by his personality altogether; or he endeavours to retrace the time which has elapsed since he last met with him, the persons amongst whom he then

was, or the actions in which he was engaged; that some one or other of these various associations may suggest the desiderated name.—But it is a most curious phenomenon, and one which, though most men are occasionally conscious of it, has been scarcely recognized by Metaphysical inquirers, that after all these expedients have been employed in vain, and the attempt to bring a particular idea to the mind has been abandoned as useless, it will often occur spontaneously a little while afterwards, suddenly flashing (as it were) before the consciousness; and this although the mind has been engrossed in the mean time by some entirely different subject of contemplation, and cannot detect any link of association whereby the result has been obtained, notwithstanding that the whole train of thought which has passed through the mind in the interval may be most distinctly remembered.* Now it is difficult, if not impossible, to account for this fact upon any other supposition, than that a certain train of action has been set-going in the Cerebrum by the voluntary exertion which we at first made; and that this train continues in movement after our attention has been fixed upon some other object of thought, so that it goes on to the evolution of its result, not only without any continued exertion on our own parts, but also without our consciousness of any continued activity. This seems to be one of the instances of what may be termed *unconscious cerebration*, to which reference has been already made (§ 787), and of which other examples will be presently adduced (§§ 818, 819). But we may here remark, as bearing on the same subject, as well as upon that of the preceding paragraph, that it is well known that impressions to which the attention is strongly directed a short time before sleep supervenes, are fixed upon the mind with remarkable force;† a fact that seems to indicate that these impressions modify the nutrition of the Brain (which is taking place with peculiar activity during the state of mental repose), and that the peculiar readiness with which they may be recalled thus depends upon organic changes of which we are unconscious, rather than upon any intentional strengthening of the links of association.

814. By Attention to our own mental states and operations, a class of Ideas is generated, of a very different character from those which are called-up by external objects; and these, being entirely dependent upon the operation of the Intellectual powers, and having no relation to sensations except as the original springs of those operations, may be termed *intellectual* Ideas, in contradistinction to the *sensational* Ideas. The former, like the latter, become the subjects of the associating tendency; and thus are combined in *Trains of Thought*. Some of these

* So frequently has this occurred within the Author's experience, that he is now in the habit of trusting to this method of recollection, where he has reason to feel sure that the desired idea is not far off, if the mind can only find its track—as when it relates to some occurrence (such as a payment of money) which is known to have taken place within a few days previously; for he has found himself much more certain of recovering it, by withdrawing his mind from the search when it is not speedily successful, and by giving himself up to the occupation appropriate to the time, than by inducing fatigue by unsuccessful efforts. And this is not his own experience only, but that of many others. The fact has been noticed by Dr. Holland ("Chapters on Mental Physiology," p. 66); from whom he has learned that the above plan has been put into successful action by many to whom he has recommended it.

† Thus it is well known to schoolboys who have a task to commit to memory, that if they can put it together correctly, however hesitatingly, over night, they can generally repeat it fluently in the morning.

intellectual ideas appear to be so necessarily excited by mental operations, even of the simplest kind, and to be so little dependent on individual peculiarities either inherent or acquired, that they take rank as *fundamental axioms* or principles of Human Thought. Such are,—the belief in our own *present existence*, or the faith which we repose in the evidence of Consciousness; this idea being necessarily associated with every form and condition of mental activity:—the belief in our *past existence*, and in our *personal identity* so far as our memory extends, which is necessarily connected with the act of Recollection; with this, again, is connected the general idea of Time:—the belief in the *external and independent existence* of the causes of our sensations, which results from the direction of the mind to the Perceptional ideas originating in them; with this is connected the general idea of Space:—the belief in the existence of an *efficient cause* for the changes which we witness around us, which springs from the perception of those changes; whence is derived our idea of Power:—the belief in the *stability of the order of nature*, or in the invariable sequence of similar effects to similar causes, which also springs directly from the perception of external changes, and seems prior to all reasoning upon the results of observation of them (being observed to operate most strongly in those whose experience is most scanty, and in relation to subjects that are perfectly new to them); but which is the foundation of all applications of our own experience or that of others, to the conduct of our lives, or to the extension of our knowledge:—lastly, the belief in *our own free will*, involving the general idea of Voluntary Power; which is in like manner a direct result of our internal perception of those mental changes which are excited by sensations. Hence it is evident that "the only foundation of much of our belief, and the only source of much of our knowledge, is to be found in the constitution of our own minds;" but it must be steadily kept in view, that these fundamental axioms are nothing else than expressions of the general fact, that the ideas in question are uniformly excited (in all ordinarily-constituted minds at least) by simple Attention to the changes in which they originate.—Among those elementary modes of thought, which arise out of the constitution of our own minds, we must also rank the ideas of Truth, Beauty, and Right, which intuitively present themselves to our consciousness, in connection with certain objects or occurrences respectively adapted to excite them; the first connecting itself especially with the operations of the Reason, the second with the production of those states of feeling which are termed Sentiments, and the third with the determinations of the Will in the guidance of conduct. *Truth* may be defined to be an apprehension of the relations of things as they actually exist; and the conception of truth, which is originally based upon sensational ideas, comes to be also applied to those which are purely intellectual. The notion of *Beauty* is one that it is very difficult to define; but it seems to consist essentially in the conformity of an external object to a certain ideal standard, by which conformity a pleasurable feeling is produced. That ideal standard is a work of the Imagination, and is generated (by a kind of automatic process) by the elimination of all those elements which we recognize as inferior, and by the intensification and completion of all those which we regard as excellent. Hence according to the æsthetic judgment which every indi-

vidual pronounces as to these particulars, will be his ideal of beauty. The notion of beauty extends itself, also, to the pure conceptions of the Intellect; and thus we may experience the sense of beauty in the recognition of a Truth. We experience the sense of beauty, too, in witnessing the conformity of conduct to a high standard of Moral excellence; which excites in our minds a pleasure of the same order, as that which we derive from the contemplation of a noble work of art. The idea of *Right* connects itself with voluntary action. We have no feeling of approval or disapproval with respect to actions that are necessarily connected with our physical well-being; but in regard to most of those which are left to our choice, it is impossible to feel indifferent; and the sphere of operation of this principle becomes widened, in proportion as the mind dwells upon the notion of Moral Obligation which arises out of it. Then, too, the idea of Right is brought to attach itself to thoughts, as well as to actions; and this, not merely because the right regulation of the thoughts is perceived to be essential to the right regulation of the conduct, but also because the mind intuitively perceives that whatever we can govern by the Will has also a moral aspect.

815. Closely connected with many of the foregoing, and arising in most minds from some or other of them by the very nature of our psychical constitution, are those ideas which relate to the Being and Attributes of the Deity. The conception which each individual forms of the Divine Nature, depends in great degree upon his own habits of thought; but there are two extremes, towards one or other of which most of the current notions on this subject may be said to tend, and between which they seem to have oscillated in all periods of the history of Monotheism. These are, *Pantheism*, and *Anthropomorphism.*—Towards the Pantheistic aspect of Deity, we are especially led by the philosophic contemplation of His agency in external Nature; for in proportion as we fix our attention exclusively upon the 'laws' which express the orderly sequence of its phenomena, and upon the 'forces' whose agency we recognise as their immediate causes, do we come to think of the Divine Being as the mere *First Principle* of the Universe, an all-comprehensive 'Law' to which all other laws are subordinate, that most general 'Cause' of which all the physical forces are but manifestations. This conception embodies a great truth, and a fundamental error. Its truth is the recognition of the universal and all-controlling agency of the Deity, and of His presence *in* Creation rather than on the outside of it. Its error lies in the absence of any distinct recognition of that *conscious volitional* agency, which is the essential attribute of Personality; for without this, the Universe is nothing else than a great self-acting machine, its Laws are but the expressions of 'surd necessity,' and all the higher tendencies and aspirations of the Human Soul are but 'a mockery, a delusion, and a snare.'—The Anthropomorphic conception of Deity, on the other hand, arises from the too exclusive contemplation of *our own* nature as the type of the Divine; and although, in the highest form in which it may be held, it represents the Deity as a being in whom all the noblest attributes of Man's spiritual essence are expanded to infinity, yet it is practically limited and degraded by the impossibility of *fully* realizing such an existence to our minds; the failings and imperfections incident to our Human nature being attributed to the Divine, in proportion as the low standard of in-

tellectual and moral development in each individual keeps down his idea of possible excellence. Even the lowest form of any such conception, however, embodies (like the Pantheistic) a great truth, though mingled with a large amount of error. It represents the Deity as a *Person;* that is, as having that Intelligent Volition, which we recognize in ourselves as the source of the power we determinately exert, through our bodily organism, upon the world around; and it invests Him, also, with those Moral attributes, which place him in sympathetic relation with his sentient creatures. But this conception is erroneous, in so far as it represents the Divine Nature as restrained in its operations by any of these limitations which are inherent in the very constitution of Man; and in particular, because it leads those who accept it to think of the Creator as "a remote and retired mechanician, inspecting from without the engine of creation to see how it performs," and as either leaving it entirely to itself when once it has been brought into full activity, or as only interfering at intervals to change the mode of its operation.—Now the truths which these views separately contain, are in perfect harmony with each other; and the very act of bringing them into combination effects the elimination of the errors with which they were previously associated. For the idea of the universal and all-controlling agency of the Deity, and of his immediate presence throughout Creation, is not found to be in the least degree inconsistent with the idea of His personality, when that idea is detached from the limitations which cling to it in the minds of those, who have not expanded their anthropomorphic conception by the scientific contemplation of Nature; on the contrary, when we have once arrived at that conception of *Force* as an expression of *Will,* which we derive from our own experience of its production, the universal and constantly-sustaining agency of the Deity is recognized in every phenomenon of the external Universe; and we are thus led to feel that in the Material Creation itself, we have the same distinct evidence of His personal existence and ceaseless activity, as we have of the agency of intelligent minds in the artistic creations of Genius, or in the elaborate contrivances of Mechanical skill, or in those written records of Thought which arouse our own psychical nature into kindred activity.

816. There is, in fact, no part of Man's psychical nature, which does not speak to him of the Divine, when it is rightly questioned. The very perception of *finite* existence, whether in time or space, leads to the idea of the Infinite. The perception of *dependent* existence, leads to the idea of the Self-existent. The perception of change in the external world, leads to the idea of an Absolute Power as its source. The perception of the order and constancy underlying all those diversities which the surface of Nature presents, leads to the idea of the Unity of that power. The recognition of Intelligent Will as the source of the power we ourselves exert, leads to the idea of a like Will as operating in the Universe. And our own capacity for reasoning, which we know not to have been obtained by our individual exertions, is a direct testimony to the Intelligence of the Being who implanted it. So are we led from the very existence of our Moral Feelings, to the conception of the existence of attributes, the same in kind, however exalted in degree, in the Divine being. The sense of Truth implies its actual existence in a being who is himself its source and centre; and the longing for a yet higher measure of it, which is expe-

rienced in the greatest force by those who have already attained the truest and widest view, is the testimony of our own souls to the Truth of the Divine Nature. The perception of Right, in like manner, leads us to the Absolute lawgiver who implanted it in our constitution; and, as has been well remarked, "all the appeals of innocence against unrighteous force are appeals to eternal justice, and all the visions of moral purity are glimpses of the infinite excellence." The aspirations of the most exalted moral natures after a yet higher state of Holiness and Purity, can only be satisfied by the contemplation of such perfection as no merely Human being has ever attained; and it is only in the contemplation of the Divine Ideal, that they meet their appropriate object. And the sentiment of Beauty, especially as it rises from the material to the spiritual, passes beyond the noblest creations of art and the most perfect realization of it in the outward life, and soars into the region of the Unseen, where alone the imagination can freely expand itself in the contemplation of such Beauty as no objective representation can embody.— And it is by combining, so far as our capacity will admit, the ideas which we thus derive from reflection upon the facts of our own consciousness, with those which we draw from the contemplation of the Universe around us, that we form the justest conception of the Divine Nature, of which our finite minds are capable. We are led to conceive of Him as the Absolute, Unchangeable, Self-Existent,— Infinite in duration,— Illimitable in space,—the highest ideal of Truth, Right, and Beauty,— the All-powerful source of that agency which we recognize in the phenomena of Nature,— the All-Wise designer of that wondrous plan, whose original perfection is the real source of the uniformity and harmony which we recognize in its operation,—the All-Benevolent contriver of the happiness of His sentient creatures,— the All-Just disposer of events in the Moral world, for the evolution of the ultimate ends for which Man was called into existence. In proportion to the elevation of our own spiritual nature, and the harmonious development of its several tendencies, will be the elevation and harmoniousness of our conception of the Divine; and in proportion, more particularly, as we succeed in raising ourselves towards that ideal of perfection which has been graciously presented to us in the "well-beloved Son of God," are the relations of the Divine Nature to our own *felt* to be more intimate. And it is from the consciousness of our relation to God, as His creatures, as His children, and as independent but responsible fellow-workers with Him in accomplishing His great purposes, that all those Ideas and Sentiments arise, which are designated as Religious, and which constitute that most exalted portion of our nature, of whose continued existence and yet higher elevation we have the fullest assurance, both in the depths of our own consciousness and in the promises of Revelation.

817. Upon the Sensational and Intellectual Ideas thus brought under the cognizance of the Mind, all acts of *Reasoning* are founded. These consist, for the most part, in the aggregation and collocation of ideas, the decomposition of complex ideas into more simple ones, and the combination of simple ideas into general expressions; in which are exercised the faculty of *Comparison*, by which the relations and connections of ideas are perceived,—that of *Abstraction*, by which we fix our attention on any particular qualities of the object of our thought, and isolate it from the rest,—

and that of *Generalization*, by which we connect together those properties which have been thus discovered to be common to a number of objects. These operations, when carefully analyzed, seem capable of reduction to this one expression,—namely, the fixation of our Attention on some particular *classes of ideas*, from among those which Suggestion brings before our consciousness; and this fixation may result, as already shown, either from the peculiar attractiveness which these classes of ideas have for us (the constitution of individual minds varying greatly in this respect), or on the determination of our own Will.—The foregoing are the purely intellectual processes chiefly concerned in the simple acquirement of knowledge, with which class of operations, the Emotional part of our nature has very little participation; and there is strong reason to believe that they may be performed *automatically* to a very considerable extent, without any other than a permissive act of Will. It is clearly by such automatic action that the above-mentioned 'fundamental axioms' or 'intuitions' are evolved; and there is not one of the operations above described, which may not be performed quite involuntarily, especially by an individual who is naturally disposed to it. Thus to some persons, the tendency to compare any new object of consciousness with objects that have been previously before the mind, is so strong as to be almost irresistible; and this, or any other original tendency, is strengthened by the habit of acting in conformity with it. So, again, the tendency to abstraction is equally strong in the minds of others, who instinctively seek to separate what is fundamental and essential in the properties of objects, from what is superficial and accidental; and their attention being most attracted by the former, they readily recognize the same characters elsewhere, and are thus as prone to combine and generalize, as others are to analyze and distinguish. It is only, in fact, when we *intentionally* divert the current of thought from the direction in which it was previously running,—when we *determine* to put our minds in operation in some particular manner,—and make a *choice of means* adapted to our end (as in the act of Recollection already described) by purposely fixing our attention upon one class of objects and excluding others,—that we can be said to use the Will in the act of Reasoning; and this exercise of it is shown by the analysis of our own consciousness, to be much rarer than is commonly supposed. Thus we may imagine a man sitting down at a fixed hour every day, to write a treatise upon a subject which he has previously thought-out; after that first effort of Will by which his determination was made, the daily continuance of his task becomes so habitual to him, that no fresh exertion of it is required to bring him to his desk; and, unless he feel unfit for his work, or some other object of interest tempt him away from it, so that he is called-upon to decide between contending motives, his Will cannot be fairly said to be brought into exercise. It may need, perhaps, some voluntary fixation of his attention upon the topics upon which he had been engaged when he last dropped the thread, to enable him to recover it so as to commence his new labours in continuity with the preceding; but when once his mind is fairly engrossed with his subject, this developes itself before his consciousness according to his previous habits of mental action; ideas follow one another in rapid and continuous succession, clothe themselves in words, and prompt the movements by which those words are expressed in writing; and this automatic action

may continue uninterruptedly for hours, without any tendency of the mind to wander from its subject, the Will being only called into play when the feeling of fatigue or the distraction of other objects renders it difficult to keep the attention fixed upon that which has previously held it by its own attractive power.*— The converse of this condition is experienced, when some powerful interest tends to draw-off the attention elsewhere, and the thoughts are found to wander continually from the subject in hand; or when, from the undue protraction of mental exertion, the state of the brain is such that the thoughts no longer develope themselves consecutively in the mind, nor shape themselves into appropriate forms of expression. In either of these cases, the intellectual powers can only be kept in action upon the pre-determined subject, by a strong effort of the Will; of this effort we are conscious at the time, and feel that we need to put-forth even a greater power than that which would be required to generate a large amount of physical force through the muscular system; and we subsequently experience the results of it, in the

* Two very remarkable instances may be noticed, in men distinguished, the one for intellectual, the other for artistic ability; in both of whom the mental action which evolved the result, seems to have been in great degree of an automatic character.—All accounts of Coleridge's habits of thought, as manifested in his conversation (which was a sort of *thinking aloud*) agree in showing that his train of mental operations, once started, went on *of itself*, sometimes for a long distance in the original direction, sometimes with a divergence into some other track, according to the consecutive suggestions of his own mind, or to new suggestions introduced into it from without. His whole course of life was one continued proof of the weakness of his Will; for, with numerous gigantic projects continually in his mind, he could never bring himself even seriously to attempt to execute any one of them; and his utter deficiency in self-control rendered it necessary for his welfare that he should yield himself to the control of others. The composition of the poetical fragment "Kubla Khan" *in his sleep*, is a typical example of automatic mental action; and almost his whole life might be regarded as a sort of waking dream, in regard to the deficiency of that self-determining power which is the pre-eminent characteristic of every really great mind. (The most striking portraiture of Coleridge's habits of conversation, is to be found in Carlyle's "Life of John Sterling.")—The whole artistic life of Mozart, from his infancy to his death, save in so far as the earlier part of it was directed by his father, may be cited as an example of the spontaneous or automatic development of musical ideas, which expressed themselves in the language appropriate to them. When only four years old, he began to write music, which was found to be in strict accordance with the rules of composition, although he had received no instruction in these. And when engaged in adult life, in the production of those works which have rendered his name immortal, it was enough for him once to fix his thoughts in the first instance upon the subject (the libretto of an opera, for example, or the words of a religious service), so as to give the requisite start and direction to his ideas, which then flowed onwards without any effort of his own; so that the whole of a symphony or an overture would develope itself in his mind, its separate instrumental parts taking (so to speak) their respective shapes, without any *intentional* elaboration. In fact, the only exercise of Will that seemed to be required on his part, consisted in the noting-down of the composition when complete; and this, under the temptations of social intercourse, and a dislike to anything like 'work,' he would sometimes postpone until the last moment. Thus it is well known that his overture to Don Giovanni was only written-out (although it must have been previously composed) during the night previous to its performance, which took place without any rehearsal. It is recorded of him, that being once asked by an inferior musician how he set to work to compose a symphony, he replied—"If you once think of *how* you are to do it, you will never write anything worth hearing. *I* write because I cannot help it." Mozart, like Coleridge, was a man of extremely weak will; he could neither keep firm to a resolution, nor resist temptation; and when not under the guidance of his excellent wife, was the sport of almost every kind of impulse. But there was probably never a more remarkable example than his musical career presents, of the automatic operation of that *creative* power which specially constitutes Genius; and his life is altogether a most interesting study to the Psychologist, as well as to the Musician. (See especially the "Life of Mozart" by Edward Holmes.)

feeling of excessive fatigue which always follows any exertion that calls the Cerebrum into extraordinary activity.

818. But we seem justified in proceeding further, and in affirming that the Cerebrum may act upon impressions transmitted to it, and may elaborate results such as we might have attained by the purposive direction of our minds to the subject, *without any consciousness* on our own parts; so that we only become aware of the operation which has taken place, when we compare the result, as it presents itself to our minds after it has been attained, with the materials submitted to the process. The ordinary experience of most persons will supply them with examples of this form of Cerebral activity. One of the simplest instances of it is to be found in the process by which we acquire a knowledge of the meaning of an author whose writings we are perusing. For, if the subject be one into which we readily enter, and if the writer's flow of thought be one which we easily follow, and his language be appropriate to express his ideas, we acquire the meaning of one *sentence* after another, without any conscious recognition of the meaning of each of the component *words;* and yet it is certain that a particular impression must have been made by each of these words upon the Cerebrum, before we can comprehend the notion which they were collectively intended to convey. It is only when the language is ill-chosen, or when we do not readily follow the author's train of thought, that we direct our attention to the signification of the individual words, and become conscious of their separate meaning. In like manner, an expert calculator will cast his eye rapidly from the bottom to the top of a column of figures, and will name the total, without any conscious appreciation of the value of each individual figure.—But in these instances, no higher act of mind is required, than the production of one complex idea out of an aggregate of simpler elements; there are cases, however, in which processes of a far more elaborate nature are carried on, without necessarily affecting our consciousness. Most persons who attend to their own mental operations, are aware that when they have been occupied for some time about a particular subject, and have then transferred their attention to some other, the first, when they return to the consideration of it, may be found to present an aspect very different from that which it possessed before it was put aside; notwithstanding that the mind has since been so completely engrossed with the second subject, as not to have been consciously directed towards the first in the interval. Now a part of this change may depend upon the altered condition of the mind itself, such as we experience when we take-up a subject in the morning with all the vigour which we derive from the refreshment of sleep, and find no difficulty in overcoming difficulties and in disentangling perplexities which checked our further progress the night before, when we were too weary to give more than a languid attention to the points to be made-out, and could use no exertion in the search for their solutions. But this by no means accounts for the *entirely new development* which the subject is frequently found to have undergone, when we return to it after a considerable interval; a development which cannot be reasonably explained in any other mode, than by attributing it to the intermediate activity of the Cerebrum, which has in this instance automatically evolved the result without our consciousness. Strange as this phenomenon may at first sight appear, it is found, when carefully

considered, to be in complete harmony with all that has been affirmed in the preceding paragraphs, respecting the relation of the Cerebrum to the Sensorium, and the independent action of the former; and looking at all those automatic operations by which results are evolved without any intentional direction of the Mind to them, in the light of 'reflex actions' of the Cerebrum, there is no more difficulty in comprehending that such reflex actions may proceed without our knowledge, so as to evolve *intellectual products* when their results are transmitted to the Sensorium and are thus impressed on our consciousness, than there is in understanding that impressions may excite muscular movements, through the 'reflex' power of the Spinal Cord, without the necessary intervention of Sensation. In both cases, the condition of this form of independent activity, is that the *receptivity* of the Sensorium shall be suspended *quoad* the changes in question, either by the severance of structural connection, or through its temporary engrossment by other objects.*

819. It is difficult to find an appropriate term for this class of operations. They can scarcely be designated as Reasoning Processes, since 'unconscious reasoning' is a contradiction in terms. The designation *Unconscious Cerebration* is perhaps less objectionable than any other.— But it must not be left out of view, that *emotional* states, or rather states which constitute emotions when we become conscious of them, may be developed by the same process; so that our feelings towards persons and objects may undergo most important changes, without our being in the least degree aware, until we have our attention directed to our own mental state, of the alteration which has taken place in them. A very common but very characteristic example of this kind of action, is afforded by the powerful attachment which often grows up between individuals of opposite sexes, without either being aware of the fact; the full strength of this attachment being only revealed to the consciousness of each, when circumstances threaten a separation, and when each becomes cognizant of the feelings entertained by the other. The existence of a mutual attachment, indeed, is often recognized by a by-stander (especially if the perceptions be sharpened by jealousy, which leads to an intuitive interpretation of many minute occurrences which would be without signification to an ordinary observer), before either of the parties has made the discovery, whether as regards the individual *self*, or the beloved *object;* the Cerebral state manifesting itself in action, although no distinct consciousness of that state has been attained, chiefly because, the whole atten-

* It may serve to give the readers of this Treatise more confidence than they might otherwise feel in the truth of the above doctrine, if the Author mentions, that, having been led to entertain it as *possible* on purely Physiological grounds, he then began to question not merely his own experience but that of others, as to the Psychological evidence of unconscious Cerebral activity. Having found enough in the results of this inquiry to convert the possibility into a *probability*, he next took an opportunity of placing his views before two of the deepest thinkers of the present day, Sir W. Hamilton and Mr. John Mill. From the former he learned that the doctrine had been advanced by Leibnitz more than two centuries since; and that the first of the above illustrations had actually been adduced by that eminent philosopher in its support. By the latter he was assured that the fact of the unconscious development of a subject of thought was so familiar to him, that, when he found it difficult to pursue an inquiry further, not seeing his way clearly through its entanglements, he was accustomed to lay it aside for weeks or even months, and to devote himself to some other object, with the full expectation (derived from frequent experience) of being able to prosecute his first investigation with diminished difficulty, whenever he might feel disposed to resume it.

tion being attracted by the present enjoyment, there is little disposition to Introspection. The fact, indeed, is recognized in our ordinary language; for we continually speak of the feelings which we unconsciously entertain towards another, and of our not becoming aware of them until some circumstances call them into activity. Here, again, it would seem as if the material organ of these feelings tends to *form itself* in accordance with the impressions which are habitually made upon it; so that we are as completely unaware of the changes which may have taken place in it, as we are of those by which passing events are registered in our minds (§ 812), until some circumstance calls forth the conscious manifestation, which is the 'reflex' of the new condition which the organ has acquired. And it may be remarked in this connection, that the Emotional state seems often to be determined by circumstances of which the individual has no distinct consciousness, and especially by the emotional states of those by whom he is surrounded; a mode of influence which is exerted with peculiar potency on the minds of children, and which is a most important element in their Moral Education.*

820. The faculty of *Imagination* is in some respects opposed in its character to that of Reason; being chiefly concerned about fictitious objects, instead of real ones. Still, it is in a great degree an exercise of the same powers, though in a different manner. Thus it is partly concerned in framing new combinations of ideas relating to external objects, and is thus an extended exercise of Conception; placing us, in idea, in scenes, circumstances, and relations, in which actual experience never found us; and thus giving rise to a new set of objects of thought. In fact, every Conception of that which has not been itself an object of perception, may, strictly speaking, be regarded as the result of the exercise of Imagination. Now the new Conceptions or mental creations thus formed, take their character, in great degree, from the Emotional tendencies of the mind; so that the previous development of particular feelings and affections will influence, not merely the selection of the objects, but the mode in which they are thus idealized. In the higher efforts of the Imagination, the mind is not so much concerned with the class of sensational ideas, as with those of the intellectual character; and the collocation, analysis, and comparison of these, by which new forms and combinations are suggested to the mind, involve the exercise of the same powers as those concerned in acts of Reasoning; but they are exercised in a different way. Whilst the Imagination thus depends upon the Intellectual powers for all its higher operations, the understanding may be said to be equally indebted to the imagination; for the ideal combinations, which are the results of the action of the latter, do not merely engage the attention of the Artist, who aims to develope them in material forms, but are the great sources of the improvement of the knowledge and happiness possessed by our race, — operating alike in the common affairs of life, by suggesting those pictures of the future which are ever before our eyes, and are our animating springs of action, with their visions of enjoyment never perhaps to be fully realized, and their prospects of anticipated evil that often prove to be an exaggeration of the reality,—prompting the

* See an admirable Discourse on 'Unconscious Influences,' by the Rev. Horace Bushnell, of Hartford (N. E.), published in the "Penny Pulpit," No. 1199.

investigations of Science, that are gradually unfolding the sublime plan on which the Universe is governed, — and leading to a continual aspiration after those highest forms of Moral and Intellectual beauty, which are inseparably connected with purity and love.

821. We have now, in the last place, to inquire into the mode in which *Volition* operates in determining the course of thought and the regulation of the conduct; — a problem of extreme difficulty, the entire solution of which may not lie within the limited sphere of Man's present capacity. The chief subject of embarrassment is rather the nature and source of the Will itself, than the conditions of its operation; for whilst a careful analysis of our own consciousness throws much light on the latter, the scientific investigation of the former tends to results which are inconsistent with our intuitive conviction of freedom, as well as with our scarcely less intuitive notion of moral responsibility. Dismissing the former question, therefore, as one which requires a much more laboured discussion than could here be appropriately bestowed upon it, we may apply ourselves to the consideration of the mode in which Volition acts (1.) upon the Corporeal organism, and (2.) upon our Psychical nature.

822. It is a fact of universal experience, that, although certain states of Mind have a remarkable influence on the Organic functions, no change in their usual course can be determined by the direct influence of the Will.* The only sensible effect which the strongest effort of Volition can produce on the bodily frame, is the excitation of *muscular contraction.* Now if we examine into the *cause* of a Volitional movement, we find it to lie, as in other instances, in a certain combination of *material conditions* with *dynamical agency* (p. 3). The aggregate of the material conditions is a state of integrity of the muscular and nervous apparatus through which the Will operates; the dynamical agency is the *effort* which we are conscious of putting-forth, and which we feel to be *the power* by which the work is done, the degree of volitional exertion required being strictly proportional to the amount of *resistance* to be overcome, and being followed by a corresponding sense of *fatigue*, which is the indication of the expenditure of force. As already pointed-out (§ 799), it is an essential condition of every Volitional action, that a distinct idea should exist of the object to be attained, and that there should be also a belief in the possibility of attaining it by the means employed; and further, the amount of power which can be put forth on any occasion, is dependent, *cæteris paribus,* upon the degree in which the attention is concentrated upon the effort, and the mind withdrawn from the contemplation of other objects. Hence it is (we have seen), that Emotional excitement may either intensify or paralyse the Volitional power, according as it determines or interferes-with the special direction of the mental energy to the object with which it is connected. But the same influence is capable of being exerted by the simple dominance of *ideas*, in certain states of mind in which the directing power of the Will over the current of thought is altogether suspended, without the destruction of the capacity for voluntary exertion of the nervo-muscular apparatus. Thus the Author has seen a man remarkable for the poverty of his muscular

* "Which of you, by taking thought, can add one cubit to his stature?" "Thou canst not make one hair white or black."

development, who shrank from the least exertion in his ordinary state, lift a 28-lb. upon his little finger alone, and swing it round his head with the greatest facility, when in that state of artificial somnambulism termed Hypnotism by Mr. Braid (§ 827); his extraordinary command of muscular power in this condition being simply due to the complete concentration of his mental energy upon the one object, and to the dominance of the idea (with which his mind was possessed by the confident assurances of Mr. Braid) that he *could* attain it with the greatest facility, — that idea not being negatived by his ordinary experience, for reasons hereafter to be stated (§ 824). On the other hand, the same individual (whilst in the hypnotic state) declared himself altogether unable to raise a handkerchief from the table, after many apparently strenuous efforts; his mind having been previously possessed by the assurance that its weight was too great for him to move.* In that curious state of artificial Reverie, which has recently attracted much attention under the inappropriate name of 'Electro-Biology' (§ 825), precisely the same phenomena may be observed; the subjects of it being prevented from performing the commonest voluntary movements, by the assurance that they *cannot* execute them, which assurance takes full possession of their minds, in virtue of their want of power to bring their ordinary experience to bear upon the idea thus introduced; whilst they may be compelled by the dominance of ideas, introduced in like manner by external suggestion, to perform actions, which, if not physically impossible to them in their ordinary state, they could not be induced to execute by any conceivable motives. — These facts are not so far removed from our ordinary experience, as might at first sight appear. For it must be within the knowledge of every one, that, when *first* attempting to perform some new kind of action, the power we feel capable of exerting depends in great measure upon the degree of our assurance of success. Of this we have a good example in the process of learning to swim; which is greatly facilitated, as Dr. Franklin pointed out, by our first taking means to satisfy ourselves of the buoyancy of our bodies in the water, by attempting to pick up an object from the bottom. And every one is aware of the assistance derived from the encouragement of others, when we are ourselves doubtful of our powers; and of the detrimental influence of discouragement or suggested doubt, even when we previously felt a considerable confidence of success.† These familiar facts show us, therefore, that

* The Author has every reason to believe that the personal character of this individual placed him above the suspicion of deceit; and it is obvious that if he had *practised* the first of the above performances (which very few, even of the strongest men, could accomplish without practice), the effect would have been visible in his muscular development. Of course, there was not an equal proof of the absence of deception in the second case as in the first; but if the reality of the first, and the validity of the explanation above given, be admitted, there need be no difficulty in the reception of the second, since it is only another manifestation of the same mental condition.

† The Author well remembers, several years ago, being among those who tested the validity of the statement put forth in Sir D. Brewster's "Natural Magic," that four persons can lift a full-sized individual from the ground, high into the air, with the greatest facility, if they all take-in a full breath previously to the effort, the person lifted doing the same. He could readily understand, upon physiological principles, that a full inspiration on the part of the *lifters* would have a certain degree of efficacy in augmenting their nervo-muscular power; but he could not perceive how the performance of the same act by the *person lifted* could have any appreciable effect; and while many of his acquaintances assured

the phenomena just described as occurring in abnormal states, are in no respect contrary to our knowledge of the conditions under which the Will operates in producing muscular movement; but afford, when rightly interpreted, a strong confirmation of the statements already made respecting the nature of those conditions.

823. The Will is exerted, however, not merely in determining the actions of the body, but also in regulating the operations of the Mind; and here again we find that its action is limited by certain conditions, the knowledge of which is of great importance. It may be said, generally, that we have no direct power of calling before our consciousness, by a volitional effort, ideas which are not already present there; thus, in the act of Recollection, we can do no more than fix our minds upon those ideas which seem most likely to recall, by an act of suggestion, the one which we desiderate (§ 813). But what we do possess, is the power of excluding some ideas, and of bringing others prominently before our mental vision; and this by the power of *Voluntary Attention*, which is the chief if not the sole means by which the sequence of our thoughts is directed by the Will. It has been already pointed-out that the Attention may be involuntarily fixed upon certain subjects of consciousness, through the attraction they exert upon the individual mind, in virtue either of its original constitution or of its acquired habitudes; it being this attraction which determines the automatic action of our faculties (§ 811). When most strongly exerted, it causes the consciousness to be so completely engrossed by one train of ideas, that the mind is, for the time, incapable of any other ideational change: sensory impressions, if felt, not being perceived; and, where the consciousness is most completely concentrated upon the internal operations, the individual being as insensible to external impressions as if he were in a profound sleep. But these automatic tendencies of the mind may be to a certain extent antagonized by the Will, which keeps them in check (just as it restrains many of the automatic impulses to bodily movement) by the special power which it exerts over the Attention. This it can detach from subjects which have at the time the greatest attractiveness to it, and can forcibly direct it to others from which the former would otherwise divert it. And in its most complete and powerful exercise (which is not within the capacity of every one), it can so completely limit the mind to one train of thought, that the state of Abstraction induced by the Will may be as complete as

him that, when all the conditions were duly observed, the body went up 'like a feather,' and that they felt satisfied of being able to support it upon the points of their fingers, he found his own experience quite different; and came to the conclusion, after much observation, that the facility afforded by this method entirely depended upon the degree in which it fulfilled the above-mentioned conditions, namely, the fixation of the attention upon the effort, and the conviction of the success of the method. Whenever the attention was distracted and confidence weakened by scepticism as to the result, the promised assistance was not experienced.—The Author may also mention, as a very characteristic illustration of the same principles, the following little circumstance communicated to him by a friend. This gentleman relates that, having been accustomed in his boyhood to play at bagatelle with other juniors of his family, the party was occasionally joined by a relative who was noted for her success at the game, and who was consequently much dreaded as an opponent; and that, on one occasion, when she was about to take her turn against him, he roguishly exclaimed, "Now, aunty, you will not be able to make a hit;" the effect of which suggestion was, that she missed every stroke,—and not only at that turn, but through the remainder of the evening.

that which in some individuals is of spontaneous occurrence. In proportion as we are able thus to concentrate our attention on the subject proper to the time, and to exclude all distracting considerations whilst pursuing the trains of thought which the contemplation of it suggests, will be our power of advantageously employing our Intellectual Faculties in the acquirement of knowledge and in the pursuit of truth; and all men who have been distinguished by their intellectual achievements, have possessed this faculty in a considerable degree. It is one which is "eminently capable of cultivation by steady intention of mind and habitual exercise;" and the more frequently it is put in practice, the easier the exercise becomes. In fact, when a man has once brought his Intellectual faculties under the mastery of his Will, to such an extent as to induce the state of Abstraction whenever he pleases, this state becomes (as it were) 'secondarily automatic;' and the fixed direction of the thoughts, which at first required a *constant* volitional effort for its maintenance, comes to be continued without any consciousness of exertion, so long as the Will may permit.—We have, in our own consciousness of effort, and in our experience of subsequent fatigue, a very strong indication that the power which thus controls and directs the current of thought, is of the same *kind* with that which calls forth Volitional movements of the body, though exerted in a different mode. And just as the strongest exertion of Will is required to produce or sustain Muscular contraction, when the sense of muscular fatigue is already strongly experienced, or when we are antagonizing a powerful automatic impulse, so in the determination of Mental effort in a particular direction, we find ourselves necessitated to make the greatest Volitional effort when we are already labouring under the sense of cerebral fatigue, or when the attention is powerfully solicited by some other attractive object. And it is after any such contest with our natural tendencies, that we experience the greatest degree of exhaustion; the merely automatic action of the Mind, which is attended with no effort, being followed by comparatively little fatigue.*

* The Author is satisfied from his own experience, that a most valuable indication may be hence drawn, in regard to the regulation of the habits of Intellectual labour. To individuals of ordinary mental activity, who have been trained in the habit of methodical and connected thinking, a very considerable amount of *work* is quite natural; and when such persons are in good bodily health, and the subject of their labour is congenial to them, —especially if it be one that has been chosen by themselves because it furnishes a centre of attraction around which their thoughts spontaneously tend to range themselves,—their intellectual operations require but little of the controlling or directing power of the Will, and may be continued for long periods together without fatigue. But from the moment when an indisposition is experienced to keep the attention fixed upon the subject, and the thoughts wander from it unless coerced by the Will, the mental activity loses its spontaneous or automatic character; and more exertion is required to maintain it volitionally during a brief period, and more fatigue is subsequently experienced from such an effort, than would be involved in the continuance of an automatic operation through a period many times as long. Hence he has found it practically the greatest economy of mental labour, to work vigorously when he feels disposed to do so, and to refrain from exertion, so far as possible, *when it is felt to be an exertion.*—Of course this rule is not applicable to all individuals, for there are some who would pass their whole time in listless inactivity if not actually spurred-on by the feeling of necessity; but it holds good for those who are sufficiently attracted by objects of interest before them, or who have in their worldly circumstances a sufficiently strong motive to exertion, to make them feel that they *must* work, the question with them being *how* they can attain their desired results with the least expenditure of mental labour.

824. But this determining power of Volition is employed, in however slight a degree, whenever the succession of thought is not *perfectly spontaneous;** whenever, in fact, we *wish* our consciousness to take a particular direction, even for the apprehension of ideas most familiar to our minds. Of this we derive the best evidence from those curious states, in which the directing power of the Will is entirely suspended, whilst yet the mind remains freely open to external impressions; a condition which shows us what we should be, if we really *were* what some writers assure us that we actually *are*, mere thinking automata, puppets moved in any direction by the pulling of suggesting-strings (§ 802 *note*). This condition presents itself spontaneously in some individuals, and may be induced in others; and it is not a little remarkable that it may occur as a modification both of the *waking* and the *sleeping* states. Of the former we have an example in ordinary *Reverie*, a state to which some persons are peculiarly prone; the characteristic of which is, that whilst, as in Dreaming, the succession of thought is entirely automatic, it is in no small degree influenced by external impressions, especially such as arise from the various phenomena of Nature. It is in minds in which the emotional and imaginative elements predominate, that we usually find the greatest tendency to reverie; and the sequence of thought, if subsequently analysed, will be found to have been chiefly determined by these tendencies. Now this sequence may conduct us to notions altogether inconsistent with our most familiar experience; and yet we accept them as realities, notwithstanding this incongruity, because the ideas to which they are opposed are not present to our minds at the time, and the dormant state of our Will prevents us from making the slightest effort to bring them before the consciousness. The state of *Abstraction*, or 'absence of mind,' is essentially the same with that of reverie; the chief difference being, that in true Abstraction, the mind is at work ratiocinatively, a certain train of thought being followed-out by the intellectual operations to its logical conclusion; it being the Philosopher who is most prone to abstraction, as the Poet is to reverie. Now it is one of the most curious phenomena of this state, that external impressions, if received by the consciousness at all, are very often *wrongly* perceived, being interpreted in accordance with the ideas which happen to be dominant in the mind at the time, instead of giving rise to those new ideas which ordinarily connect themselves with them, in virtue of the individual's habitual experience. The records of 'absence of mind' are full of amusing instances of such misinterpretation. Nothing seems too strange for the individual to believe, nothing too absurd for him to do under the influence of that belief. Thus of Dr. Robert Hamilton, a well-known

* It is hoped that the reader will have been made sufficiently aware by the preceding explanations, that by the terms 'spontaneous' or 'automatic' succession of thought, it is intended to designate that sequence of states of consciousness, in which every one is the immediate resultant of that which preceded it, whether that were ideational or sensational. Thus the current of thought is alike 'spontaneous,' when it flows-onwards in one continuous channel, being directed by a single dominant idea which absorbs the whole attention; and when the mind is freely accessible to external impressions, and may be entirely guided by them. The phenomena of Reverie, Abstraction, and Somnambulism (as will be presently seen) afford illustrations of *both* these states; which, though apparently opposite in their nature, are really characterized by the same essential feature, namely, the absence of the directing power of the Will.

Professor at Aberdeen, who was the author of many productions distinguished for their profound and accurate science, their beautiful arrangement, and their clear expression, we are informed that, "In public, the man was a shadow; pulled off his hat to his own wife in the streets, and apologized for not having the pleasure of her acquaintance; went to his classes in the college on the dark mornings with one of her white stockings on the one leg, and one of his own black ones on the other; often spent the whole time of the meeting in moving from the table the hats of the students, which they as constantly returned; sometimes invited them to call on him, and then fined them for coming to insult him. He would run against a cow in the road, turn round, beg her pardon, call her 'Madam,' and hope she was not hurt. At other times, he would run against posts, and chide them for not getting out of his way." *

825. A state may be artificially induced in many individuals, by a continued fixed gaze at an object at a moderate distance, which is the same as that of Reverie and Abstraction in regard to the complete suspension of the directing power of the Will over the current of thought, but which differs from these in the readiness with which the mind may be possessed with ideas suggested to it through the medium of language. This state has been commonly known by the name *Electro-Biological*, from the mode in which its induction was originally practised; † but it is now more frequently designated by the very inappropriate term *Biological*. The subject of it may be truly characterized as a *thinking automaton*, the whole course of whose ideas may be determined by suggestions operating from without; and his mind, having in itself no power of altering the course of these in even the slightest degree, is cut off from all recourse to previous experience for the examination of their correctness or the determination of their fallacy. The senses of the biologized subject are freely accessible to external impressions; but, as in the case of the 'absent' man, his perception of these is governed by the ideas which may be dominant in his mind at the time; and he may be consequently led to any kind of absurd misinterpretation of them. Yet his state of mind is not so far removed from his ordinary condition, as to prevent his usual habits of thought and feeling from displaying themselves; and he has

* See "New Monthly Magazine," vol. xxviii p. 510.—The Author has heard from an old pupil of Dr. Hamilton an anecdote so singularly illustrative of this peculiar condition, that he cannot refrain from here introducing it. The Professor, walking one day along the High Street with the front of his breeches open (no very unusual occurrence with him), chanced to encounter a woman in a white apron; and apparently mistaking this apron for his own shirt, he laid hold of it, and began to push it into the situation which his shirt should occupy!

† The "Electro-Biologists," as they term themselves, at first maintained that a wonderful virtue resided in the little disk of copper with a zinc centre, to which they directed the gaze of their 'subjects.' It is now universally admitted, however, that *any* object which serves as a *point d'appui* for the fixed gaze, is equally efficacious.—The Author has no hesitation in avowing his belief in the *reality* of the phenomena, which are described as occurring in this state; these having been presented to himself and to other scientific inquirers, by numerous individuals, on whose honesty and freedom from all disposition to deceive themselves or others, implicit reliance could be placed. All *public* exhibitions, the performers in which are of questionable character, are of course open to the obvious fallacy of intentional deceit. With regard to the *interpretation* of these phenomena, however, he entirely dissents from the statements commonly made, to the effect that the Will of the 'biologized' subject is entirely under the control of that of the operator; since he regards the latter as having no other influence over the former, than through the *suggestions* which his language and manner convey.

in most cases a perfect recollection of what has taken place, when he returns to his usual condition of mental activity, though sometimes the recollection does not extend to particulars. All the phenomena of the 'biologized' state, when attentively examined, will be found to consist in the occupation of the mind by the *ideas* which have been suggested to it, and in the influence which these ideas exert upon the actions of the body. Thus the operator asserts that the 'subject' cannot rise from his chair, or open his eyes, or continue to hold a stick; and the 'subject' thereby becomes so completely possessed with the fixed belief of the impossibility of the act, that he is incapacitated from executing it, *not* because his will is controlled by that of another, but because his will is in abeyance, and his muscles are entirely under the guidance of the conviction which for the time possesses his mind. So again, when he is made to drink a glass of water, and is assured that it is coffee, or wine, or milk, that assurance, delivered in a decided tone, makes a stronger impression on his mind than that which he receives through his taste, smell, or sight; and not being able to judge and compare, he yields himself up to the 'dominant idea.'* Here, again, we perceive that it is not really the *will* of the operator which controls the *sensations* of the subject; but the *suggestion* of the operator which excites a corresponding *idea*, the falsity of which is not corrected, simply because the mind of the subject, being completely engrossed by it, cannot apprehend the truth less forcibly impressed on it through his own senses. The same general statement applies to what has been designated as 'control over the memory.' The subject is assured that he cannot remember the most familiar thing, his own name for example; and he is prevented from doing so, not by the will of the operator, but by the conviction of the impossibility of the mental act, which engrosses his own mind, and by the want of that voluntary control over the direction of his thoughts, which alone can enable him to *recal* the desiderated impression. And the abolition of the sense of personal identity,—Mr. A. believing himself to be Mrs. B., or Mrs. C. believing herself to be Mr. D., and acting in conformity with that belief,—is induced in the same mode; the assurance being continually repeated, until it has taken full possession of the mind of the 'subject,' who cannot so direct his thoughts as to bring his familiar experience to antagonize and dispel the illusive idea thus forced upon him. The phenomena presented by different 'biologized subjects' are by no means the same; for in some individuals it is the relation of the mind to bodily action which is most remarkably affected, in others it is the relation of the perceptive consciousness to sensations, and in others (especially those who are naturally of an imaginative and excitable disposition) it is the course of thought and of emotion which is most completely under external guidance. It is frequently to be observed, moreover, that some capability of

* It is very curious to observe, in some instances, the perplexity arising from the contrariety between the opposing sensory impressions. The mind seems unable to reconcile this contrariety, and yields itself up to the impression which is most strongly felt. Sometimes it is convinced by the repeated assurances of the operator, so long as the *taste* alone is opposed to them, but attaches a superior importance to the indications of *sight*; in other individuals, again, the indications of sight may be put aside, and yet the 'subject' cannot be made to believe what is in opposition to his sense of taste. There are some individuals who can never be thus played upon, notwithstanding that their muscular movements and their purely mental conceptions are completely amenable to this kind of direction.

volitional effort still remains, so that the 'subject' endeavours to resist the commands of the operator; but this may usually be subdued by the emphatic reiteration of the assurance "You *must* do this," or "You *cannot* do that," which, when it takes complete possession of the mind of the subject, reduces the will to a state of entire powerlessness.*

826. It is obvious that, if the account here given of the condition of the Mind and of the mode of its operation on the Body, in the states of natural and artificial Reverie and Abstraction, be correct, all the actions performed in these states must be regarded as essentially *automatic* in their nature; the course of thought being entirely determined by the associations previously formed, and all the bodily movements being the direct manifestations of the *ideas* which possess the mind at the time, just as the ordinary movements of 'expression' are of its *emotions.* And it is, therefore, in these remarkable phases of psychical existence, that we have the clearest manifestation of the power which Cerebral changes possess, to produce muscular movement independently either of Volition or of Emotion; an action which may be distinguished as *ideo-motor,* since it only takes place when these changes are of a kind to awaken the ideational consciousness; and which is a true 'reflex' action of the Cerebrum. The same designation may be fairly applied also, to all those actions performed by us in our ordinary waking state, which are rather the automatic expressions of the ideas which are dominant in our minds at the time, than prompted by distinct volitional effort (§ 817). Of this kind, the act of expressing the thoughts in language, whether by speech or writing, may be considered as a good example; for the attention may be so completely given-up to the choice of words and to the composition of the sentences, that the movements by which these words are uttered by the voice or traced on paper no more partake of the truly volitional character, than do those of our limbs when we walk through the streets in a state of Abstraction. And it is a curious evidence of the influence of Ideas, rather than of the agency of the Will, in producing them, that, as our conceptions are a little in advance of our speech or writing, it occasionally happens that we mis-pronounce or mis-spell a word, by introducing into it a portion of some other whose turn is shortly to come, its place in the sentence which is in process of formation being a little further on; or it may be that the whole of the anticipated word is substituted for the one which ought to have been expressed. Now it is obvious that there could be neither any consciously-formed intention of breaking the regular sequence, nor any volitional effort to do so; and the result is evidently due to the superior vividness with which the idea of the anticipated word is present to the mind, as compared with that of the word which the course of construction requires. It is the *dominant idea,* then, which

* It is worthy of particular notice in this connection, that this want, not really of power to move, but of belief in the possession of the power, is a frequent characteristic of that state of the nervous system which is commonly designated as 'Hysterical;' and that here, also, the most efficacious treatment consists in the encouragement of volitional efforts on the part of the patient to put the paralysed limbs in action, and in the repetition of assurances that she *will* recover the use of them, if she only take the appropriate means. The expectation of recovery excited in other ways, produces the same effect; and thus it has been that many pseudo-miracles have been wrought on this class of patients by religious enthusiasts, and that many wonderful cures have been effected by the supposed influence of Mesmerism. All that is wanted is that state of confident anticipation, which is commonly designated as Faith.

determines the movement, the Will simply permitting it; and the more completely the Volitional power is directed to other objects, the more completely automatic are the actions of this class. They may, indeed, come to be performed even without the consciousness, or at least without the remembered consciousness, of the agent; as we see in the case of those who have the habit of 'thinking aloud,' and who are subsequently quite surprised on learning what they have uttered. The one-sided conversation of some persons, who are far more attentive to their own trains of thought, than they are to what may be expressed by others, and who are allowed to proceed with little or no interruption, is often a sort of 'thinking aloud.' *—All that is here stated is in perfect accordance with the general principle already laid down (§ 683), that in proportion as the higher channels of activity are obstructed, will the excitation of nerve-force manifest itself through the lower. For, whilst the ordinary sequence is for external impressions to excite sensations, for sensations to excite ideas, and for ideas (after becoming the subject of reasoning processes of greater or less complexity) to issue in volitional determinations, the direct action of *ideational* changes in the Cerebrum on the motor system, when either the Will is in abeyance or is entirely directed to mental operations, seems quite as natural as the immediate reaction of *sensational* changes through the Sensory ganglia, or of *impressional* changes through the Spinal Cord.

827. The phenomena of *Somnambulism* are no less important in a scientific point of view, when they are regarded under the same aspect. They differ from those already described, in that they occur in a state of consciousness so far distinct from the ordinary waking condition, as not to be connected with it by the ordinary link of Memory; and although the course of thought in Somnambulism usually manifests the directing influence of previous habits, and the knowledge of persons and things possessed during the waking state may be readily brought before the mind, yet nothing which occurs during the state of Somnambulism is ever retraced spontaneously, or can be brought back by an act of recollection. Impressions upon the nervous system, however, are sometimes left by strong emotional excitement, which give rise to subsequent feelings of discomfort, of whose origin the individual is entirely unconscious.† The phenomena of Somnambulism are so various, that it is difficult to give any general definition that shall include the whole; but it is a condition which is common to all forms of this state, that the controlling power of the Will over the current of thought is entirely suspended, and that all the actions are directly prompted by the ideas which possess the mind; and the differences chiefly arise out of the mode in which the succession of ideas is directed, this being in some cases a coherent sequence through the whole of which some one dominant impression may be traced, whilst in other instances it is more or less completely determinable by external suggestions.—The first of these phases, which is nearly akin to the state of Abstraction, is frequently seen in *natural* Somnambulism; in which a train of reasoning is often carried-out with remarkable clearness and cor-

* This was pre-eminently the case with Coleridge, whose peculiar habits have been already noticed, § 817, *note*.

† See a very curious example of this kind, which fell under the Author's own observation, narrated in the Article 'Sleep,' in the "Cyclop. of Anat. and Phys.," vol. iv. p. 693.

rectness, and its results expressed in appropriate language, or otherwise acted-on. Thus, a mathematician may work-out a difficult problem, an orator make a speech appropriate to the occasion on which he supposes himself to be called-up, or an author may compose and commit to writing poetry or prose, upon the subject which occupies his thoughts. But it is a frequent defect of the intellectual operations carried-on in this condition, that, through the complete absorption of the attention by one set of considerations, no account is taken of others which ought to modify the conclusion; and this, although it may be palpably inconsistent with the teachings of ordinary experience, is not felt to be so, unless the latter should happen to present themselves unbidden to the thoughts.—The second of the phases above mentioned, which is especially seen in the *artificial* Somnambulism induced by the (so-called) Mesmeric process, or by the fixed gaze at a near object (as practised by Mr. Braid under the name of Hypnotism), is essentially the same as that of the 'biological' condition, save in the different relation which they respectively bear to the waking state; for there is the same readiness to receive new impressions through the senses (the visual sense, however, being generally in abeyance), and the same want of persistence in any one train of ideas, the direction of the thoughts being entirely determined by the suggestions which are introduced from without. In either of these extreme forms of Somnambulism, and in the numerous intermediate phases which connect the two, the consciousness seems entirely given-up to the one impression which is operating upon it at the time; so that whilst the attention is exclusively directed upon any object, whether actually perceived through the senses, or brought suggestively before the mind by previous ideas, nothing else is felt. Thus there may be complete insensibility to bodily pain, the somnambulist's whole attention being given to what is passing in his mind; yet in an instant, by directing the attention to the organs of sense, the anæsthesia may be replaced by ordinary sensibility; or, by the fixation of the attention on any one class of sensations, these shall be perceived with most extraordinary acuteness, whilst there may be a state of complete insensibility as regards the rest. So, again, when the attention of the somnambulist is fixed upon a certain train of thought, whatever may be spoken in harmony with this is heard and appreciated, but what has no relation to it, or is in discordance with it, is entirely disregarded.—It is among the most curious of the numerous facts which Mr. Braid's investigations upon artificial Somnambulism have brought to light, that the suggestions derived from the 'muscular sense' have a peculiar potency in determining the current of thought. For if the face, body, or limbs be brought into an attitude that is expressive of any particular emotion, or that corresponds with that in which it would be placed for the performance of any voluntary action, the corresponding mental state,—that is, either an emotional condition affecting the general direction of the thoughts, or the idea of a particular action,—is called-up in respondence to it. Thus, if the hand be placed upon the vertex, the Somnambulist will frequently, of his own accord, draw his body up to its fullest height, and throw his head slightly back; his countenance then assumes an expression of the most lofty pride, and the whole train of thought is obviously under the domination of this feeling, as is manifested by the replies which the individual makes to interrogatories, and by the tone

and manner in which these are delivered. Where the first action does not of itself call forth the rest, it is sufficient to straighten the legs and spine, and to throw the head somewhat back, to arouse the emotion, with its corresponding manifestation, in its full intensity. If, during the most complete domination of this emotion, the head be bent forwards and the body and limbs be gently flexed, the most profound humility then takes its place. So, again, if the angles of the mouth be gently separated from one another, as in laughter, a hilarious disposition is immediately generated; and this may be made to give place to moroseness, by drawing the eyebrows towards each other and downwards upon the nose, as in frowning.* So, again, if the hand be raised above the head, and the fingers be flexed upon the palm, the idea of climbing, swinging, or pulling at a rope is called-up in such as have been used to this kind of exertion; if, on the other hand, the fingers be flexed when the arm is hanging down at the side, the idea suggested is that of lifting a weight; and if the same flexure be made when the arm is advanced forwards in the position of striking a blow, the idea of fighting is at once aroused, and the Somnambulist is very apt to put it into immediate execution.†

828. The state of *Dreaming* presents us with another series of phenomena, which fall under the same general category with the preceding. In fact, between Dreaming and Somnambulism there is every stage of gradation; for that form of Somnambulism in which the actions are expressive of ideas that arise spontaneously within the mind, instead of being prompted by external suggestions, may be designated as an acted dream; whilst, on the other hand, there are states of Dreaming, in which the bystander is able in greater or less degree to trace the current of thought and feeling, by the words occasionally uttered, or by the play of the countenance of the sleeper. Instances might be cited, which it would be very difficult to assign to either one of these conditions, so completely do they partake of the character of both; as, for example, the well-known case of the officer who amused his friends by acting his dreams during the expedition to Louisburgh, the course of these dreams being capable of direction by whispering into the sleeper's ear, especially if this was done by a friend with whose voice he was familiar.‡ It is usually considered to be a distinction between Dreaming and Somnambulism,

* The Author has not only repeatedly witnessed all these effects, as produced by Mr. Braid upon 'hypnotized' subjects, of whom several had never been previously in that condition, and had no idea whatever of what was expected from them; but he has been assured by a most intelligent medical friend, who has paid special attention to the psychological part of this inquiry, that having subjected himself to Mr. Braid's practice, and having been only partially thrown into the 'hypnotic' state, he distinctly remembers everything that was done, and can retrace the uncontrollable effect upon his emotional state, which was produced by this management of his muscular apparatus.

† On one occasion on which the Author witnessed this result, a violent blow was struck, which chanced to alight upon a second somnambulist within reach; *his* combativeness being thereby excited, the two closed, and began to belabour one another with such energy, that they were with difficulty separated. Although their passions were at the moment so strongly excited, that even when separated they continued to utter furious denunciations against each other, yet a little discreet manipulation of their muscles soon calmed them and restored them to perfect good-humour.

‡ This case is detailed by Dr. Abercrombie ("Inquiries concerning the Intellectual Powers," 5th Ed., p. 277,) on the authority of Dr. Gregory, to whom it was related by a gentleman who witnessed it. A case of a very similar nature, the subject of which was a medical student at Edinburgh, is related in Smellie's "Philosophy of Natural History."

that the senses are in complete abeyance in the former state, while they are more or less capable of action in the latter. But we have seen that the sensibility to external impressions may be partially or even completely suspended in Somnambulism; whilst, on the other hand, it may exist to a slight extent in Dreaming, as in the instance just quoted. And it is quite certain that even where sensations are not recognized by the mind as proceeding from external objects, they may affect the course of its own thoughts; so that the character of the dreams may be in some degree predetermined by such an arrangement of sensory impressions as is likely to modify them. This is especially the case in regard to the dreamy state induced by certain narcotics, such as the Hachisch (a preparation of *Cannabis Indica*) employed for this purpose in the East; for the emotional condition of the individual under its influence is entirely under the control of external impressions; so that those who give themselves up to the intoxication of the *fantasia*, take care to withdraw themselves from everything which could give their delirium a tendency to melancholy, or excite in them anything else than feelings of pleasurable enjoyment.*— The difference between the state of mind in ordinary Dreaming and that which is characteristic of Somnambulism, is most remarkable in regard to the rapidity and incoherence of the trains of thought in the former state, as compared with the slowness and steadiness of the mental action usually observed in the latter. It is true that in ordinary dreaming there is sometimes a remarkable degree of consistency in the mental operations; for reasoning processes may be carried-on correctly, and even (through that freedom from distraction which is consequent upon the suspension of external disturbing agencies) with remarkable vigour and completeness, especially when they are the continuation of a train of thought on which the mind had been previously engaged during the waking hours; and music, poetry, &c., may be composed, which, if afterwards remembered and written-down, is found to be in accordance with the rules of taste. Such, however, is not the usual character of the state of dreaming; for more commonly there is an entire want of any ostensible coherence between the ideas which successively present themselves to the consciousness; and we are completely unaware of the incongruousness of the combinations which are thus formed. It has been well remarked that "nothing surprises us in dreams." All probabilities of 'time, place, and circumstance' are violated; the dead pass before us as if alive and well; even the sages of antiquity hold personal converse with us; our friends upon the antipodes are brought upon the scene, or we ourselves are conveyed thither, without the least perception of the intervening distance; and occurrences, such as in our waking state would excite the strongest emotions, may be contemplated without the slightest feeling of a painful or pleasurable nature. Facts and events long since forgotten in the waking state, present themselves to the mind of the dreamer; and many instances have occurred, in which the subsequent retention of the knowledge thus re-acquired has led to most important results.† But one of the most remarkable of all the peculiarities in

* See the Author's article 'Sleep,' in the "Cyclop. of Anat. and Phys.," vol. iv. pp. 688-690; and Moreau "Du Hachisch et de l'Aliénation Mentale, Etudes Psychologiques," p. 67.

† See a number of such cases in Dr. Abercombie's "Inquiries concerning the Intellectual Powers."

the state of dreaming, is the *rapidity* with which trains of thought pass through the mind; for a dream in which a long series of events has seemed to occur, and a multitude of images has been successively raised-up, has been often certainly known to have occupied only a few minutes, or even seconds, although whole years may seem to the dreamer to have elapsed. There would not appear, in truth, to be any limit to the amount of thought which may thus pass through the mind of the dreamer, in an interval so brief as to be scarcely capable of measurement; as is obvious from the fact, that a dream involving a long succession of supposed events, has often distinctly originated in a sound which has also awoke the sleeper, so that the whole must have passed during the almost inappreciable period of transition between the previous state of sleep and the full waking consciousness.* Hence it has been argued by some, that *all* our dreams really take place in the momentary passage between the states of sleeping and waking; but such an idea is not consistent with the fact already referred-to, that the course of a dream may often be traced, by observing the successive changes of expression in the countenance of the dreamer. It seems, however, that those dreams are most distinctly remembered in the waking state, which have passed through the mind during the transitional phase just alluded-to; whilst those which occur in a state more allied to Somnambulism, are more completely isolated from the ordinary consciousness.—There is a phase of the dreaming state, which is worthy of notice as marking another gradation between this and the vigilant state; that, namely, in which the dreamer has a consciousness that he is dreaming, being aware of the unreality of the images which present themselves before his mind. He may even make a voluntary and successful effort to prolong them if agreeable, or to dissipate them if unpleasing; thus evincing the possession of a certain degree of that directing power, the entire want of which is the characteristic of the true state of Dreaming.

829. Very nearly allied to the states of Somnambulism and Dreaming, are those of *Delirium* and of *Mania*, which graduate almost imperceptibly into one another; being chiefly distinguished by the degree and kind of excitement which they respectively exhibit, and by the nature of the bodily states with which they are connected. The loss of voluntary control over the current of thought is the primary element of both these conditions; and the gradual weakening of this may be frequently traced, when the transition from the normal state is not so rapid as to prevent its various steps from being watched. The *artificial delirium* produced by Intoxicating agents affords peculiar facilities for this kind of observation; and among these agents, there is none whose operation is so interesting in this respect as the Hachisch. The first effect of a dose of this substance, as described by M. Moreau (Op. cit.), is commonly to produce a moderate exhilaration of the feelings, and an unusual activity of the intellectual powers; but this activity gradually frees itself from the

* The only phase of the waking state, in which any such intensely rapid succession of thoughts presents itself, is that which is now well attested as a frequent occurrence, under circumstances in which there is imminent danger of death, especially by drowning; the whole previous life of the individual seeming to be presented instantaneously to his view, with its every important incident vividly impressed on his consciousness, just as if all were combined in a picture, the whole of which could be taken-in at a glance.

control of the Will. The individual feels himself incapable of fixing his attention upon any subject; his thoughts being continually drawn-off by a succession of ideas which force themselves (as it were) into his mind, without his being in the least able to trace their origin. These speedily occupy his attention, and present themselves in strange combinations, so as to produce the most fantastic and impossible creations. By a strong effort of volition, however, the original thread of the ideas may be recovered, and the interlopers driven away. These 'lucid intervals' successively become of shorter and shorter duration, and can be less frequently procured by a voluntary effort; for the internal tempest becomes more and more violent, the torrent of (apparently) disconnected ideas increases in vehemence, so as completely to arrest the attention, and the mind is at last entirely given up to it, and at the same time withdrawn from the perceptive consciousness of external things, although, as already pointed-out (§ 828), it is by no means removed from the influence of sensory impressions. The succession of ideas has at first less of incoherence than in ordinary dreaming, the ideal events not departing so widely from possible realities; and the disorder of the mind is at first manifested in errors of perception, in false convictions, or in the predominance of one or more extravagant notions. These false ideas are generally not altogether of an imaginary character, but are originally called into existence by external impressions, these being erroneously interpreted through the disordered action of the perceptive faculty; thus, for example, among the most common perversions are those relating to time and space, minutes seeming hours, hours being prolonged into years, and all idea of time being at last obliterated, so that past and present are confounded together as in ordinary dreaming; whilst in like manner streets may appear of an interminable length, the people at the other end seeming to be at a vast distance; the mind having a tendency to *exaggerate* every impression made upon the consciousness, especially those which affect the emotional state. The effect of a full dose, however, is at last to produce the complete withdrawal of the mind from the contemplation of external things, and entirely to suspend the action of the Will over the current of thought; and the condition then comes to be nearly the same as that of ordinary Dreaming, the chief difference consisting in the readiness with which the emotions may be excited in those who are under the influence of the Hachisch, and in the degree in which these are amenable to external influences.—The following concise and faithful description of the ordinary Delirium of disease, will show how completely it corresponds in all its essential characters with that which is induced by the introduction of intoxicating agents into the blood. "In its highest degree, it is a complete disturbance of the intellectual actions; the thoughts are not inactive, but rather far more active than in health; they are uncontrolled and wander from one subject to another with extraordinary rapidity; or, taking up one single subject, they twist and turn it in every way and shape, with endless and innumerable repetitions. The thinking faculty seems to have escaped from all control and restraint, and thought after thought is engendered without any power of the patient to direct and regulate them. Sometimes they succeed each other with such velocity, that all power of perception is destroyed, and the mind, wholly engrossed with this rapid development of thoughts, is unable to perceive impressions

made upon the senses; the patient goes on unceasingly raving, apparently unconscious of what is taking place around him; or it may be, that his senses have become more acute, and that every word from a bystander, or every object presented to his vision, will become the nucleus of a new train of thought; and, moreover, such may be the exaltation of his sensual perception, that subjective phenomena will arise in connection with each sense, and the patient fancies he hears voices or other sounds, whilst ocular spectra in various forms and shapes appear before his eyes and excite further rhapsodies of thought." * It must be remarked that there is usually a greater disorder of the perceptive faculty in Delirium, than in ordinary Dreaming; for in the former condition, the erroneous images are more vividly conceived-of as having an existence external to the mind, than they are in the latter, the illusory visual and auditory perceptions having all the force of reality, and being the original *sources* of ideas, instead of (as seems to be rather the case in dreaming) their *products.*†

830. Those more violent forms of Delirium in which there is considerable emotional disturbance, pass by almost imperceptible gradations into the state of *Mania,* which is usually characterized by the combination of complete derangement of the intellectual powers, with passionate excitement upon every point which in the least degree affects the feelings. There is, however, a considerable amount of variety in the phases of Mania, depending upon differences in the relative degree of *intellectual* and of *emotional* disturbance. For there may be such a derangement of the former, as gives rise to complete incoherence in the succession of ideas, so that the reasoning power is altogether suspended; and yet there may be at the same time an entire absence of emotional excitement, so that the condition of the mind is closely allied to that of dreaming or of

* See Dr. Todd's 'Lumleian Lectures, on the Pathology and Treatment of Delirium and Coma,' in the "Medical Gazette," 1850, vol. xlv. p. 703.—A circumstance was mentioned to the Author, whilst he was a student at Edinburgh, which remarkably illustrates the influence of suggestions derived from external sources, in determining the current of thought. During an epidemic of Fever, which had occurred some time previously, and in which an active delirium had been a common symptom, it was observed that many of the patients of one particular physician were possessed by a strong tendency to throw themselves out of the window, whilst no such tendency presented itself in unusual frequency in the practice of others. The Author's informant, himself a distinguished Professor in the University, explained this tendency by what had occurred within his own knowledge, as follows :—His friend and colleague, Dr. A., was attending a patient, Mr. B., who seems to have been the first to make the attempt in question; impressed with the necessity of taking due precautions, Dr. A. then visited Dr. C., *in whose hearing* he gave directions to have the windows properly secured, as Mr. B. had attempted to throw himself out. Now Dr. C. distinctly remembers, that although he had not previously experienced any such desire, it came upon him with great urgency as soon as ever the idea was thus suggested to him ; his mind being just in that state of incipient delirium, which is marked by the temporary dominance of some one idea, and by the want of voluntary power to withdraw the attention from it. And he deemed it probable that, as Dr. A. went on to Mr. D., Dr. E., &c., and gave similar directions, a like desire would be excited in the minds of all those who happened to be in the same impressible condition.

† In true Dreaming, the sensational consciousness is entirely closed to the outward world ; and all the images which we may believe we see, or the sounds that we fancy ourselves to hear, seem to result from changes in the Sensorium excited by Cerebral influence ; but in Delirium there is an evidently disordered action of the Sensorium itself, of which spectral illusions and other 'subjective sensations' are the manifestation. This is particularly obvious in that form of Delirium which is known as *delirium tremens.*

rambling delirium. On the other hand, the intellectual powers may be themselves but little disturbed, the trains of thought being coherent, and the reasoning processes correctly performed; but there may be such a state of general emotional excitability, that nothing is *felt* as it should be, and the most violent passion may be aroused and sustained by the most trivial incidents, or by the wrong ideas which are formed by the mind as a consequence of their misinterpretation (§ 796). Between these two opposite states, and that in which the disturbance affects at the same time the intellectual and the emotional part of the Mental nature, there is a complete succession of transitional links; but, under all phases of this condition (these often passing into each other in the same individual), there is one constant element, namely, the deficiency of Volitional control over the succession of ideas. This deficiency appears to be a primary element in those forms which essentially consist in Intellectual disturbance; whilst in those of which Emotional excitement is the prominent feature, it seems rather to result from the overpowering mastery that is exercised over the Will, by the states of uncontrollable passion which succeed each other with little or no interval. It seems probable, however, from the phenomena of Intoxication (§ 829), that the very same agency which is the cause of the undue Emotional excitability, also tends to produce an absolute diminution in the power of Volitional control.

831. From the state of Mania, we naturally pass to those more persistent forms of *Insanity*, in which there is some settled disorder in the action of the Mind. Although this may arise from a perversion of any part of the psychical nature, yet a partial or complete deficiency in the Volitional control over the current of thought, and consequently over the actions which are the expressions of it, seems to be a characteristic feature of every form of Insanity; and it is this, which, in so far as it exists, ought to be considered as rendering the individual irresponsible for his actions.—It is chiefly (but not solely) in those cases in which the Cerebral power has been weakened by a succession of attacks of Mania, Epilepsy, or some other disorder which consists in a perverted action of the whole organ, that we find the *Intellectual* powers specially and permanently disordered; the succession of thought becoming incoherent, and the perception of those relations of ideas on which all reasoning processes depend, being more or less completely obscured. The failure usually shows itself *first* in the power of Volitional direction, and especially in the faculty of Recollection; in proportion as the mind is unable to bring the results of past experience to bear on its present operations, do these lose their connectedness and consistency; and at last all the ordinary links of association appear to be severed, and (as in the most incoherent kinds of Dreaming) the succession of thoughts cannot be accounted-for on any known principles of psychical action. All this may occur with or without emotional excitement; not unfrequently the latter occurs in paroxysms, which interrupt the otherwise tranquil life of the subjects of this form of Insanity, and it is not at all incompatible with this condition, that there should be a special excitability upon some one point, which, owing to the annihilation of the Volitional controlling power, acquires a temporary predominance whenever it is called into play. It is the general characteristic, however, of this form of Insanity, that there are no *settled* delusions; the mind not being disposed to dwell long upon

any one topic, but wandering off in a rambling manner, so as speedily to lose all trace of the starting-point. Such patients are unable to recollect what passed through their thoughts but a few minutes previously; if any object of desire be placed before them, which it requires a consistent reasoning process to attain, they are utterly unable to carry this through; and the direction of their desires is perpetually varying, and may be readily altered by external suggestion. Cases of Intellectual Insanity, depending (as this form of the disease usually does) upon structural disorder of the Cerebrum, are less amenable to treatment than are those of the other forms presently to be described; and their tendency is usually towards complete fatuity.

832. There may, however, be no primary disorder of the Intellectual faculties; and the Insanity may essentially consist in a tendency to disordered Emotional excitement; which affects the course of thought, and consequently of action, without disordering the reasoning processes in any other way than by supplying wrong materials to them. Now the emotional disturbance may be either *general* or *special;* that is, there may be a derangement of feeling upon almost every subject, matters previously indifferent becoming invested with strong pleasurable or painful interest, things which were previously repulsive being greedily sought, and those which were previously the most attractive being in like manner repelled; or, on the other hand, there may be a peculiar intensification of some one class of feelings or impulses, which thus acquire a settled domination over the whole character, and cause every idea with which they connect themselves to be presented to the mind under an erroneous aspect. The first of these forms, now generally termed *Moral Insanity*, *may* and frequently *does* exist without any disorder of the Intellectual powers, or any delusion whatever; it being (as we shall presently see) a result of the generality of the affection of the Emotional tendencies, that no one of them maintains any constant hold upon the mind, one excitement being (as it were) driven out by another. Such patients are among those whose treatment requires the nicest care, but who may be most benefited by judicious influences. Nothing else is requisite, than that they should exercise an adequate amount of self-control; but the best-directed moral treatment cannot enforce this, if the patient do not himself (or herself*) cooperate. Much may be effected, however, as in the education of children, by presenting adequate *motives* to self-control; and the more frequently this is exerted, the more easy does the exertion become. — The more limited and settled disorder of any one portion of the Emotional nature, however, gives an entirely different aspect to the character, and produces an altogether dissimilar effect upon the conduct. It is the essential feature of this state, that some one particular tendency acquires a dominance over the rest; and this may happen, it would seem, either from an extraordinary exaggeration of the tendency, whereby it comes to overmaster even a strongly-exercised Volitional control; or, on the other hand, from a primary weakening of the Volitional control, which leaves the predominant bias of the individual free to exercise itself. Again, the exaggerated tendency may operate (like an ordi-

* This form of Insanity is particularly common among females of naturally 'quick temper,' who, by not placing an habitual restraint upon themselves, gradually cease to retain any command over it.

nary Emotion) either in directly prompting to some kind of action which is the expression of it; or in modifying the course of thought, by habitually presenting erroneous notions upon the subjects to which the disordered feeling relates, as the basis of Intellectual operations. The first of these forms of Monomania is that which is known as *impulsive* Insanity; and the recognition of its existence is of peculiar importance in a juridical point of view. For whilst the Law of England only recognizes as *irresponsible,* on the ground of Insanity, those who are incapable of distinguishing right from wrong, or of recognizing the consequences of their acts, it is unquestionable that many criminal actions are committed under the irresistible dominance of some insane impulse, the individual being at the time perfectly aware of their evil nature and of his amenableness to punishment.* Such an impulse may lead the subject of it to kill, to commit a rape, to steal, to burn, and so on, and this without the least intention of doing injury to another; and many instances have occurred, in which the individuals thus affected have voluntarily withdrawn themselves from the circumstances of whose exciting influence they were conscious, and have even begged to be put under restraint.—It is a remarkable fact, moreover, and one that strikingly confirms the view of the nature of Emotional states which has been here advocated, that the insane impulse appears to be not unfrequently the expression of a dominant *idea,* with which there is no such association of pleasurable feeling as makes the action prompted by it an object of *desire,* but which operates by taking full possession of the mind, and by forcing (so to speak) the body into the movements which express it. The individual thus affected regards him-

* The following very characteristic example of the Homicidal form of impulsive Insanity, is given in one of the recent Reports of the Morningside (Edinburgh) Lunatic Asylum.—The case was that of a female, who was not affected with any disorder of her intellectual powers, and who laboured under no delusions or hallucinations, but who was tormented by "a simple abstract desire to kill, or rather, for it took a specific form, to strangle. She made repeated attempts to effect her purpose, attacking all and sundry, even her own nieces and other relatives; indeed, it seemed to be a matter of indifference to her *whom* she strangled, so that she succeeded in killing some one. She recovered, under strict discipline, so much self-control as to be permitted to work in the washing-house and laundry, but she still continued to assert that she 'must do it,' that she was 'certain she would do it some day,' that she could not help it, that 'surely no one had ever suffered as she had done,'—was not hers 'an awful case;' and, approaching any one, she would gently bring her hand near their throat, and say mildly and persuasively, 'I would just like to do it.' She frequently expressed a wish that all the men and women in the world had only one neck, that she might strangle it. Yet this female had kind and amiable dispositions, was beloved by her fellow-patients, so much so that one of them insisted on sleeping with her, although she herself declared that she was afraid she would not be able to resist the impulse to get up during the night and strangle her. She had been a very pious woman, exemplary in her conduct, very fond of attending prayer-meetings, and of visiting the sick, praying with them, and reading the Scriptures, or repeating to them the sermons she had heard. It was the second attack of insanity. During the former, she had attempted suicide. The disease was hereditary, and it may be believed that she was strongly predisposed to morbid impulses of this character, when it is stated that her sister and mother both committed suicide. There could be no doubt as to the sincerity of her morbid desires. She was brought to the Institution under very severe restraint, and the parties who brought her were under great alarm upon the restraint being removed. After its removal, she made repeated and very determined attacks upon the other patients, the attendants, and the officers of the Asylum, and was only brought to exercise sufficient self-control by a system of rigid discipline. This female was perfectly aware that her impulses were wrong, and that if she had committed any act of violence under their influence, she would have been exposed to punishment. She deplored, in piteous terms, the horrible propensity under which she laboured."

self as the victim of a *necessity* which he cannot resist, and may be perfectly conscious (as when the impulse proceeds from a strong desire) that what he is doing will be injurious to others or to himself. This state bears a close resemblance to that of the 'biologized' subject, who is peremptorily told, "You *must* do this," and does it accordingly (§ 825); and it is one that is particularly liable to be induced in persons who habitually exercise but little Volitional control over the direction of their thoughts, by the influence of suggestions from without, and especially by occurrences which fix themselves strongly upon their attention.*

833. Now although the existence of any morbidly-exaggerated impulse, leading to the commission of acts which must be regarded as truly Insane, may be fairly considered as constituting *Monomania*, yet that term is usually restricted to those forms of Insanity in which there are positive *delusions* or *hallucinations*, that is to say, fixed beliefs which are palpably inconsistent with reality. These delusions are not attributable to perversions of the reasoning process, but arise out of the perverted Emotional state. This gives rise, in the first place, to a mis-interpretation of actual occurrences in accordance with the prevalent state of the feelings (§ 796); but when the disorder has lasted some time, ideas which the imagination at first presents under a very transient aspect, are habitually dwelt-upon in consequence of the interest with which they are invested, and at last become realities to the consciousness of the individual, simply because he has not brought them to the test of actual experience. When the mind has once yielded itself up to the dominance of these erroneous ideas, they can seldom be dispelled by any process of reasoning; for it results from the very nature of the previous habits of thought, that the reasoning powers are weakened, and that the volitional control, through

* To this condition are to be referred many of the insane actions which are commonly set down to the account of *Imitation.* This term would be best restricted to that state of mind, in which there is an *intention* to imitate; for what is called 'involuntary imitation' is merely the expression of the fact, that the consciousness of the performance of a certain act by one individual, gives rise to a tendency to its performance by the other. Thus the excitement of the act of yawning by the sight or the sound of it in another, is a simple phenomenon of consensual movement proceeding from an *exciting sensation.* And in like manner, the commission of suicide or homicide, after an occurrence of the same kind which has previously fixed itself strongly upon the attention, is an *ideo-motor* action, prompted by a *suggesting idea.* Thus, it is well known that after the suicide of Lord Castlereagh, a large number of persons destroyed themselves in a similar mode. Within a week after the "Pentonville Tragedy," in which a man cut the throats of his four children and then his own, there were two similar occurrences elsewhere. After the trial of Henriette Cornier for child-murder, which excited a considerable amount of public discussion on the question of homicidal insanity, Esquirol was consulted by numerous mothers, who were haunted by a propensity to destroy their offspring.—The following is a remarkable example of the *sudden* domination of a morbid impulse, to which no tendency seems to have been previously experienced, and which appears to have been altogether devoid of any emotional character. Dr. Oppenheim of Hamburgh, having received for dissection the body of a man who had committed suicide by cutting his throat, but who had done this in such a manner that his death did not take place until after an interval of great suffering, jokingly remarked to his attendant,—"If you have any fancy to cut your throat, don't do it in such a bungling way as this; a little more to the left here, and you will cut the carotid artery." The individual to whom this dangerous observation was addressed, was a sober, steady man, with a family and a comfortable subsistence; he had never manifested the slightest tendency to suicide, and had no motive to commit it. Yet, strange to say, the sight of the corpse, and the observation made by Dr. O. suggested to his mind the idea of self-destruction; and this took such firm hold of him that he carried it into execution, fortunately, however, without duly profiting by the anatomical instructions he had received; for he did not cut the carotid, and recovered.

want of exercise, can no longer be exerted. And consequently, although a vigorous determination to get rid of the ideas which are felt to be erroneous, and to keep down the emotional tendency whose exaggeration is the essence of the disorder,—in other words, a strong effort of self-control,—may be effective in an early stage of this condition,* yet, when the wrong habits of thought have become settled, little can usually be done by way of direct attack upon them; and the most efficacious treatment consists in the encouragement of the general habit of self-control, and in the withdrawal of the mind, so far as may be possible, from the morbid state of action, by presenting to it other sources of interesting occupation.

834. Returning now from the consideration of these Pathological conditions of Mind (as they may be not unfairly designated) to the examination of the Psychical constitution of Man in the state of normal activity of all his faculties, we shall find that very important data may be drawn from these sources, with regard to the *modus operandi* of the Will, and the manner in which our conduct is determined. For we have seen that, in so far as the directing influence of the Will over the current of thought is suspended, the individual becomes a thinking automaton, destitute of the power to withdraw his attention from any idea or feeling by which his mind may be possessed, and as irresistibly impelled, therefore, to act in accordance with this, as the lower animals are to act in accordance with their instincts. In so far, therefore, as this directing influence is not

* See an excellent little essay by the Rev. J. Barlow, on "Man's Power over himself to prevent or control Insanity."—It may be well for the Author to state, that he was led, several years since, to the formation of the view above enunciated with regard to the emotional source of most if not all the delusions of the Insane, by the careful observation of a case in which the gradual formation of such delusions could be traced, and in which the varying tenacity of their hold over the belief (which sometimes appeared disposed to get rid of them) corresponded exactly with varying degrees of intensity of the dominant emotion. Having been led, by his interest in this case, to make particular inquiries as to the point in question, among those whose experience of Insanity has been far more extensive than his own, he has obtained from them full confirmation of the view above expressed.—It is not a little interesting, in this connexion, as well as in the additional relation which it indicates between Insanity and the various phases of Dreaming, Delirium, &c., that the *particular delusion* seems often to be suggested by accidental circumstances, the mind being previously under the influence of the morbid tendency which gave the peculiar *direction* to the thoughts. Thus we find it mentioned in the "Morningside Report," from which we have already quoted, that the Queen's public visit to Scotland seemed to give a special direction to the ideas of several individuals who became insane at that period, the attack of insanity being itself in some instances traceable to the excitement induced by that event. One of the patients, who was affected with puerperal mania, believed that, in consequence of her confinement having taken place on such a remarkable occasion, she must have given birth to a person of royal or divine dignity. During the religious excitement which prevailed at the time of the 'disruption' of the Scotch Church, an unusually large number of patients were admitted into the various asylums of Scotland, labouring under delusions connected with religion; the disorder having here also doubtless commenced in an exaggeration of this class of *feelings*, and the erroneous *beliefs* having been formed under their influence. Again, in the Report of the same Institution for 1851, it is stated that, as in former instances, "the current topics of the day gave colouring and form to the delusions of the disordered fancy. We have thus had no less than five individuals admitted during the year, who believe themselves the victims of Mesmeric agency,"—a sort of 'Mesmeric mania' having been prevalent in Edinburgh during that period,—"three of the inmates talked much of California, and of the bags full of gold which they had obtained from the diggings; and one of them arrived at the persuasion that his body was transmuted into gold."

exercised, the succession of trains of thought which occupy the consciousness (associated, or not, with feelings that give them an *emotive* character) must be considered as dependent on the 'reflex action' of the Cerebrum; the nature of this action being determined, not merely by the original constitution of the organ, but by the mode in which it has been subsequently exercised; its nutrition taking place in such conformity to the impressions made upon it, and to the modes in which it is habitually directed by the Will, that it *grows-to* these, so that a new organization thus comes to be established, by which habits of thought are determined, such as would not have arisen from its original constitution.* The variety of phases which these different states present, is chiefly dependent upon the following elements;—(1) the relative degree in which the Mind is in a state of receptivity for external impressions, or is attending only to what passes within itself; (2) the degree in which the coherence of the successive states is maintained by the continuance and right operation of the preformed associations, so that trains of thought are consistently carried-out, and reasoning processes correctly performed; and (3) the degree in which the normal operation of the intellectual faculties is disturbed by emotional excitement, either general, or limited to one class of feelings. The influence of the *first* of these elements is remarkably seen in the contrast between natural and artificial Reverie (§§ 824, 825); also between some forms of natural and artificial Somnambulism (§ 827); and not less between different forms of Insanity, since in this last condition we find some patients constantly brooding over particular trains of thought, and almost incapable of being turned from the contemplation of these by external suggestions, whilst others are no less remarkable for the instability of their mental states, and for the readiness with which a new direction may be given to the thoughts by sensory impressions. The influence of the *second* element is strikingly manifested in the difference between the various phases of the state of Dreaming, and in the contrast between the incoherence of the commoner forms of this, and that consistency in the trains of thought which generally characterizes the state of Somnambulism; but it is yet more remarkably displayed in those forms of Delirium and Insanity, which are especially characterized by the complete *confusion* of the Intellectual powers, all previous states of consciousness being (as it were) jumbled-together, and the order of their recurrence, and the nature of the new combinations which may arise out of them, being irreducible to any principle of orderly sequence. The influence of the *third* element is well seen in those forms of artificial Reverie and Somnambulism, in which the *feelings* as well as the *ideas* admit of being played-upon by external influences; for it is easy to bring the mind of the subject under the domination of any particular emotion, by taking the appropriate means to excite it;† and, so long as this may continue,

* See Dr. Laycock's Essay 'On the Reflex Function of the Brain,' in the "Brit. and For. Med. Review," vol. xix. p. 298.—If it be thought that in the above expressions, there is too much of a *Materialistic* character, the Author would beg to refer-back to the antecedent portions of this inquiry, and especially to §§ 804–6, as showing to what extent he regards the *organization* of the Cerebrum as determining its mode of *psychical activity*.

† We have seen how remarkably the emotions may be played-upon, in the 'hypnotic' state, by muscular associations (§ 827); in the 'biologized' state, it is often sufficient to ask

the language and actions most obviously display its impress. But it is in Insanity that we best see the influence of Emotional states upon the course of thought and of action; for here we find them supplying impulses to bodily action, which the weakened Will cannot resist, although the intellect distinctly apprehends the evil consequences of such actions; or, on the other hand, we find them directing the whole course of mental activity, giving a wrong colour to all the ideas which are related to them, and so fixing the attention upon the trains of thought founded upon these, that they come to attain a complete domination over the mind, and hence over the conduct, to which they supply *motives* of such potency that the Will can neither resist them nor withdraw the mind from attending to them.

835. Thus, then, we see that in all those states in which the directing power of the Will over the current of *thought* is suspended, the course of *action* is determined by some *dominant idea*, which for the time has full possession of the mind, and from which the individual has no power of withdrawing his consciousness; the *motive power* of this idea being such as either impels to action by a feeling of internal necessity (analogous to that which prompts the reflex actions of the Cranio-Spinal axis), or solicits it by the anticipation of pleasure in its result or of pain in abstinence from it. On the other hand, the man in full possession of his psychical capacity, whilst equally amenable with those in the foregoing states to the influence of the motive power of ideas, differs from them all in this most important particular,—that he has the power of refraining from action under the immediate pressure of motives, and of so far *modifying their relative force* by the mode in which he contemplates them, that their original balance may be completely altered; and hence his ultimate determination, whilst still governed by the predominance of motives, may be entirely different from that on which he would have acted if he had given way to his first impulse. For just as we may direct our Intellectual operations by an exercise of Volition, so as to fix upon certain ideas only, out of the many which present themselves to our consciousness, and to limit our attention to certain peculiar aspects of these (§ 823), so may we fix our attention upon any one or more among the motives which tend to determine our action, and keep these (as it were) in a strong light before the mind's eye, whilst by withdrawing our attention from others we virtually throw them into the background, just as we can do with regard to objects of sensation. And further, by calling the Reasoning powers into operation, and bringing them to bear upon the questions at issue, so as to follow out each of the modes of action that are before the mind to its probable consequences, the Will indirectly brings a set of new motives, arising out of these consequences, before the judgment; and these, at first overlooked, may become important elements in the decision. On the other hand, it may be that in thus reasoning-out the probable consequences of an action, motives which at first presented themselves in great strength, lose more or less of their force, and even become altogether futile.—It is in these modes that 'second thoughts' generally prove to be best, save where selfish considerations are brought to take the place of primary generous impulses;

the 'subject'—"Why are you so angry," "Why are you so sad," &c.,—to induce these conditions respectively, the suggestions being here conveyed verbally, instead of through the muscular sense.

whilst a hasty determination often leads to wrong action, because all the motives that should be taken into account have not been duly weighed.*

836. Now if we examine into the different kinds of *Motive Powers*, which, under the permission or the intentional direction of the Will, are the sources of Human action, we shall find that they may be ranged under the following heads :—(1) *Previously-acquired Habits*, which automatically incite us to do as we have been previously accustomed to do under the like circumstances, without the idea of prospective pleasure or pain, or of right or wrong, being at all present to our minds. The formation of Habits, both of thought and action, seems referable to the psychical principle of Contiguous Association (§ 807) and to the physiological principle of Nutritive Assimilation (§ 591), which, in regard to the operations of the Cerebrum, seem to be only different expressions of the same fact; namely, that whatever mode of activity has been once strongly impressed on the organ, this has a tendency to perpetuate itself. In so far as the Will yields to this tendency, instead of controlling it, the individual becomes the slave of *routine;* and this condition is often very remarkably presented by persons who are deficient in Volitional power, as it is also among the lower animals, from whose actions we may derive our best illustrations of what Habit will do, when it is not under the direction of any higher principle.† The tendency to habitual action is so

* It has been held by some, that when a man is struggling with a temptation, and the motives to good and the motives to evil are nearly in equilibrium, like weights in the two scales of the balance, the Will acts as an independent preponderating power, like a hand pushing-down the scale-beam on one side. It appears to the Author, however, to be much more conformable to the results of a careful examination of our own conduct, to regard the Will as imparting an augmented gravity (as it were) to the weights on one side, by directing attention to their value, and by indirectly making additions to them, in the manner stated above ; whilst it diminishes the force of those on the other side, by preventing the mind from giving its attention to them, and also (it may be) by virtually abstracting some of them from the scale.

† It is not uncommon to meet with Idiots, in whom the tendency to the automatic recurrence of modes of action once impressed on the consciousness is extremely remarkable. The following is stated by Miss Martineau in regard to a youth under her own observation, who, in consequence of early injury to the brain, never acquired the power of speech, or of understanding the language of others, or of in any way recognizing other minds; but was at the same time strongly affected by sensory impressions. "He could endure nothing out of its position in space or its order in time. *If any new thing was done to him at any minute of the day, the same thing must be done at the same minute every day thenceforward.*" Thus, although he disliked personal interference, his hair and nails having been one day cut at ten minutes past eleven, the next day, and every day after, at ten minutes past eleven, he "as if by a fate," brought comb, scissors, and towel ; and it was necessary to cut a snip of hair before he would release himself. Yet he had no knowledge whatever of the measurement of time by clocks and watches, and was no less minutely punctual in his observances when placed beyond the reach of these aids. So in regard to form, number, and quantity, his actions were equally methodical. He occupied himself much in making paper-cuttings, which were remarkable for their symmetry. If, when he was out of the room, a brick were taken from the heap with which he amused himself, he would pass his hand over them, spread them a little, and then lament and wander about till the missing one was restored. If seven comfits had once been put into his hand, he would not rest with six ; and if nine were given, he would not touch any until he had returned two. ("Letters on the Laws of Man's Nature and Development," p. 71.)—It would be easy to adduce multitudes of analogous instances from the actions of animals, especially such as are purposely *trained-to* particular habits, by taking advantage of the principle of 'contiguous association,' which seems to be peculiarly strong in Dogs, Horses, &c. And the recurrence of particular actions at particular intervals of time, without any means of consciously estimating its passage, or any incidents that can suggest the return of the period, is a very curious indication of the degree in which organic

universally recognized as an important part of our psychical nature, that Man has been said to be 'a bundle of habits.' Where the habits have been judiciously formed in the first instance, the tendency is an extremely useful one, prompting us to do that spontaneously, which might otherwise require a powerful effort of the Will :* but, on the other hand, if a bad set of habits have grown-up with the growth of the individual, or if a single bad tendency be allowed to become an habitual spring of action, a far stronger effort of Volition will be required to determine the conduct in opposition to them. This is especially the case, when the habitual idea possesses an Emotional character, and becomes the source of *desires*; for the more frequently these are yielded-to, the more powerful is the solicitation they exert.—(2). *Emotional States,* which incite us to particular actions, either by the expectation of gratification in the act itself or in some consequence which our reason leads us to anticipate from it, or by the expectation of pain if the act be not performed. All those *desires* and *aversions* which have so large a share in determining our conduct, come under this category; and to it must likewise be referred all those considerations which are simply *prudential*, these usually having reference to the *remoter* effects which our actions are likely to have upon our own welfare or upon that of others, and thus bringing before the mind, as elements in its determination, certain additional objects of desire or aversion.—(3). *Notions of Right and of Duty,* which, so far as they attach themselves to our actions, give them a *moral* and *religious* character. These may act simply as *ideas,* whose coercive power depends upon the intensity with which they are brought before the mind; but they obtain a much stronger influence, when they acquire an Emotional character from the association of the feeling of *desire* with the idea of *obligation;* that is, when we feel a *wish* to do that which we are conscious we *ought* to do. This association is one, which it is peculiarly within the capability of the Will to cherish and strengthen. And still more powerful is the operation of these combined motives, when a constant *habit* of acting upon them has been formed; for the strongest desires are then immediately repressed, the strongest aversions cease to exert an influence, when once the question is looked-at in its moral aspect, and a clear perception has been attained of its right and its wrong side.†

changes in the Nervous System, once determined by a certain number of repetitions, tend to perpetuate themselves. Thus a dog that has been accustomed to receive food at a certain hour and place every day, will come in search of it with extraordinary punctuality ; and the horse of a commercial traveller, after going the same journey a few times, will stop at the houses of all his master's customers ; and when he has been pulled-up at a new point on one journey, will spontaneously stop at the same point on the next,—a fact of which the Author has personal knowledge.

* This is especially the case with regard to habits of Intellectual exertion, which are in themselves peculiarly free from any emotional complication. The Author can speak from long and varied experience, of the immense saving of exertion which arises from the formation of *methodical habits* of mental labour ; which cause the ordinary routine to be performed with a far less amount of fatigue, than would be required on a more desultory system. Even here, however, care should be taken to avoid allowing one's-self to be so much the slave of habits, that all mental labour, save that which is undertaken at a particular time, or in a particular place, becomes difficult and wearisome.

† The difference between the *habitual*, the *prudential*, and the *moral* aspects of the very same action, may be made apparent by a very simple illustration.—We will suppose that a man has been accustomed to take a ride every day at a particular hour ; his whole nature so

837. It has been usually considered by Moralists and Theologians, that *Conscience*, or the *Sense of Duty*, is an autocratic faculty, which unmistakably dictates what is right in each individual case, and which should consequently be unhesitatingly obeyed as the supreme and unerring guide. Now this view of the case is attended with practical difficulties, which make it surprising that it can ever have been entertained. For it must be obvious to every one who carefully considers the matter, that whilst *a notion of right and wrong*, attaching itself to certain actions, is as much a part of the moral nature of every individual, as the feeling of *pleasure* or *pain* attaching itself to certain states of consciousness is of his sensational nature, yet the determination of *what* is right and *what* is wrong is a matter in great degree dependent upon education, habits of thought, conventional associations, &c.; so that the moral standard of no two men shall be precisely alike, and the moral standards of men brought up under entirely different circumstances shall be of the most opposite nature.* So, whilst the notion of a God sustaining any direct relation to us, involves the notion of *Duty*, which attaches itself to all actions with which he can be considered as having any concern, the dictates of this sense will vary with the ideas entertained respecting the character and requirements of the Deity; and actions may be sincerely regarded as an acceptable sacrifice by one class of religionists, which are loathed as barbarous and detestable by another. Moreover, in what have been designated as "cases of conscience," the most enlightened Moralist may have a difficulty in deciding what is the right course of action, simply because the moral sense finds so much to approve on both sides, that it cannot assign a preponderance to either. And the same difficulty attends the determination of Duty, in many peculiar contingencies; each of two or more possible modes of action being recommended by its conformity to the divine law on certain points, whilst it seems opposed to it on others. Thus, individuals in whose characters the love of *truth* and

accommodates itself to the *habit*, that he feels both mentally and physically uncomfortable at any interruption to the usual rhythm. But suppose that, just as the appointed hour comes round, the sky becomes overcast, threatening the rider with a drenching if he perseveres in his intention; his decision will then be founded on a *prudential* consideration of the relative probabilities of his escaping or of his being exposed to the shower, and of how far the enjoyment he may derive from his ride is likely to be replaced by the discomfort of a thorough wetting. But suppose, further, that instead of taking a mere pleasure-ride, a medical man is about to set forth on a professional visit to a patient whose condition requires his aid; a new motive is thus introduced, which alters the condition of the whole question, making it no longer one of prudence only, but one of *morality*. Another motive which should give the question a moral aspect, would be consideration for himself, and the risk of life or health he might run; this should be decisive where the motive which impels him to the act in question is merely that of self-gratification; but if it bring into antagonism his duty to his patient and his desire to benefit him, and on the other hand his duty to himself and his regard for the ulterior welfare of those who may be immediately dependent upon him, the question has its right and its wrong aspect on both sides, and the right may only be determined after a careful balance of probabilities. Such moral conflicts are continually occurring amongst medical practitioners in regard to exposure to the severity of the weather, to dangerous infection, or to risks of other kinds; and the decision will mainly depend upon the previously formed habits, on the one hand of disregarding all considerations connected with self, on the other of attaching special weight to them.

* Without having recourse to the strange estimates of right and wrong which prevail amongst Savage nations, for an illustration of this position, it may be sufficient to compare the different views *conscientiously* entertained on the question of Slavery, by high-minded, estimable, and Christian men and women in different parts of the American Union.

of *justice* and the *benevolent* affections are the prominent features, and who would shrink with horror from any violation of these principles of action for any selfish purpose whatever, are sorely perplexed when they are brought into collision with each other; a strong motive to tell a falsehood being presented by the desire to protect a defenceless fellow-creature from unmerited oppression or death.*—If, then, neither the Moral Sense nor the Sense of Religious Duty affords a clear and unvarying rule of action in each individual case, it is evident that the determination of what is *right* and *wrong* must be a matter of *judgment;* the rule of Moral action being based on a comparison of the relative nobility of the motives which impel us to either course, and being decided by the preference which is accorded to one motive or combination of motives above another.† If it be asked, how are the relative values of these motives to be decided, the answer must be sought in the general consciousness of Mankind, which is found to be more and more accordant in this respect, the more faithfully it is interpreted, the more habitually it is acted-on, and the more the whole intelligence is expanded and enlightened. It is this tendency towards universal agreement, which shows that there is really as good a foundation for Moral science in the

* Thus if a man, who might be urged to conceal a fugitive slave near the Canadian frontier, were to refuse to do so merely on the fear of unpleasant consequences to himself, he would be justly branded with the character of a cold-hearted coward; but if his refusal should proceed from the conviction that the divine law requires the preference of rigid truthfulness over every other motive, and that, by concealing the suppliant he should be forced into a violation of that law, he cannot be blamed even by those who believe that the law of compassion written upon our hearts is at least equally imperative.—Similar difficulties beset the upholders of the non-resistance creed, which teaches that *love* is the all-powerful principle in the moral world, and that it should entirely supersede all those impulses of our nature which lead us to oppose force to force, and to resist an unjust and unprovoked assault. Here, again, we might readily understand and sympathize with those who consider that the fear of personal suffering does not warrant our doing a severe injury to another in warding-off a threatened attack; but when the question comes to be, not of *self*-defence, but of protection to others who are helpless dependents upon our succour, and who are bound to us by the closest ties of natural affection, we feel that the comparative nobility of the latter motive warrants actions which our individual peril might scarcely justify.

† This view of the nature of Conscience will be found more fully developed in the "Prospective Review" for November 1845, pp. 587–9.—"Every moral judgment," it is well remarked by the reviewer, "is *relative;* and involves a comparison of (at least) two terms. When we praise what *has been* done, it is with the coexistent conception of *something else that might have been* done; and when we resolve on a course as *right*, it is to the exclusion of some other that is *wrong*." This is why we cannot attach any moral character to the actions of animals that are performed under the direction of a blind undesigning instinct, leaving them no choice between one course and another; nor to those which are executed by human beings, even when possessed of their full intelligence, under the domination of impulses which they have it not in their power to restrain; nor, again, to those performed by individuals whose moral sense has either never been awakened, or has been so completely misdirected by early education, that their standard of right and wrong is altogether opposite to that which the enlightened conscience of mankind agrees in adopting. But, although there are doubtless many cases in which criminal actions are committed under the impulse of passions (such as anger, lust, &c.) which the individual has not at the moment the power to control, and although he must be absolved from moral responsibility *quoad* the immediate motives of those particular actions, yet these motives too frequently derive all their force from the habit of yielding to their promptings in lesser matters, which gradually gives them a dominance, such as the Will (weakened by want of exercise in the habit of self-restraint) is unable to resist. Hence the criminal *action* is to be regarded as but the expression of a long previous course of criminal *thought*, for which, in so far he could have otherwise directed it, the individual may legitimately be held responsible.

psychical nature of Man, as there is for that of Music in the pleasure which he derives from certain combinations and successions of sounds. So, again, the more elevated are the religious ideas of Mankind in regard to the character and will of the Deity, the more will they approach to a general accordance in regard to what constitutes Religious Duty; and the complete coincidence which exists between the dictates of the Christian law and the highest principles of pure Morality, prevents one set of motives from ever coming into antagonism with the other. The *Conscience* of the religious man, indeed, may be said to be the *resultant* of his Moral sense, combined with the idea of Duty which arises out of his sense of relation to the Deity. With the former are closely associated all those emotions and propensities, which render him considerate of the welfare of his fellow-men, as of his own; and with the notion of duty to God are closely united the desire of His favour, the fear of His displeasure, the aspiration after His perfection, all which act like other motives in deciding the Will. Their relative force on any occasion, as compared with that of the lower propensities and sensual desires, greatly depends on the degree in which they are *habitually* brought to influence the mind; and it is in its power of fixing the contemplation on those higher considerations which ought to be paramount to all others, and of withdrawing it from the lower, that the Will has the chief influence in the direction of the conduct according to the dictates of Virtue.

838. From the general survey which we have now taken of the phenomena of Mind, it seems to be the obvious conclusion that these phenomena essentially consist in *a succession of states of consciousness;* and that this succession takes place, like the phenomena of the Material Universe, under certain determinate conditions. We have seen that, in those actions of the Nervous system (as of other parts of the body) in which the Will is not concerned, we have simply to consider the two elements of which we take account in all scientific inquiry; namely, the force that operates, and the organized structure on and through which it operates, —in other words, the dynamical agency, and the material conditions. And if we could imagine a being to grow up from infancy to maturity, with a mind in the state of that of a 'biologized' subject (§ 825), we should see that it would be strictly correct to speak of his character as formed *for* him and not *by* him; all his thoughts, feelings, and actions being but the reflex of his own nature upon the impressions made upon it; and that nature being determined in part by original constitution, and in part by the mode in which it is habitually called into action.—This last condition is one that is peculiar to a living and growing organism; and it is one which cannot be too strongly or too constantly kept in mind. A mere inorganic substance reacts in precisely the same mode to mechanical, chemical, electrical, or other agencies, however frequently these are brought to bear upon it, provided it has been restored to its original condition; thus water may be turned into steam, the steam condensed into water, and the water raised into steam again, any number of times, without the slightest variation in the effects of the heat and cold which are the efficient causes of the change. But every kind of activity peculiar to a living body, involves (as has been repeatedly shown) a change of structure; and the formation of the newly-generated tissue receives such an influence from the conditions under which it originates,

that all its subsequent activity displays their impress.—This view, indeed, must be extended to that remarkable *hereditary transmission* of psychical character, which presents itself under circumstances that entirely forbid our attributing it to any agency that can operate subsequently to birth, and which it would seem impossible to account-for on any other hypothesis, than that the formative capacity of the germ determines the subsequent development of the Brain, as of other parts of the body, and (through this) its mode of activity, in accordance with the influences under which that germ was first impregnated. And thus what we speak of as the 'original constitution' of each individual, is in great part (if not entirely) determined by the conditions, dynamical and material, of the parent-organisms; a convincing proof of which general fact, is afforded by a careful examination of the parental constitution and habits, in a large proportion of cases of Idiocy.* Whatever may be the congenital constitution, however, there can be no question that this is liable to great modification from external influences, both such as directly affect its physical conditions, and such as operate through the consciousness, in determining the course of thought and feeling, before the individual has acquired any self-determining power. Of this influence of physical agencies, we have a typical example in the phenomena of Cretinism; since, although the conditions under which that state is developed have not yet been precisely determined, no one can reasonably doubt that they are such as act in the first instance in modifying the nutrition and activity of the bodily organism in general, and of the Nervous system in particular.

839. From the time when the Human being first becomes conscious that he has a power within himself of *determining the succession* of his mental states, from that time does he begin to be a free agent; and in proportion as he exerts that power, does he emancipate himself from the domination of his constitutional or automatic tendencies. It is a principle now recognized by all the most enlightened educators, that the development of this power of self-control ought to be the object of all nursery discipline; and the process of its acquirement is very gradual. When an infant is excited to a fit of passion by some unpleasant sensation, its nurse attempts to restore its equanimity by presenting some new object to its attention, so that the more recent and vivid pleasurable impression may efface the sense of past uneasiness. As the infant grows into childhood, the judicious parent no longer trusts to mere sensory impressions for the diversion of the passionate excitement, but calls-up in its mind such ideas and feelings as it is capable of appreciating, and endeavours to keep the attention fixed upon these, until the violence of the emotion has subsided; and recourse is had to the same process, whenever it is desired to check any tendency to action which depends upon the selfish propensities,—appeal being always made to the highest motives which the child is capable of recognizing, and punishment being only had recourse-to, for the purpose of supplying an additional set of motives when all others fail. For a time, this process of external suggestion may need to be continually repeated, where there are strong impulses whose unworthy character calls for

* A most valuable collection of data on this subject is afforded by Dr. Howe's admirable 'Report on Idiocy' made to the Legislature of Massachusetts, of which an abstract is contained in the "American Journal of the Medical Sciences," April, 1849.

repression; but if it be judiciously adapted and consistently persevered-in, a very slight suggestion serves to recall the superior motives to the conflict. And in further space, the child comes to feel that he has *himself* the power of recalling them, and of controlling his urgent impulses to immediate action. The power of self-control, thus usually acquired in the first instance in regard to those impulses which directly determine the conduct, gradually extends itself to the habitual succession of the thoughts; and in proportion as this is brought under the direction of the Will, does the individual become capable of forming his own character, and therefore truly responsible for his actions.—It must not be forgotten, however, that the power of self-control may be turned to a bad as well as to a good account; and that the value of its results will entirely depend upon the *direction* in which it is employed. The thoughts may be so determinately drawn away from the higher class of motives, the suggestions of conscience so habitually disregarded, and the whole attention so completely fixed upon the gratification of selfish or malevolent propensities, that the Human nature acquires far more of the Satanic than of the Divine character; the highest development of this type (if the term may be permitted) being displayed by those, who use their power of self-control for the purposes of hypocrisy and dissimulation, and cover the most malignant designs under the veil of friendship. Such men (whose portraiture is presented by our great Dramatist in the character of Iago) show us to what evil account the highest intellect and the most powerful will may be turned, when directed by the baser class of motives; and we cannot but feel that they are far more degraded in the moral scale, than those who, having never learned to control their animal propensities, and being unconscious of the very existence of a higher nature within themselves, simply obey the promptings of their automatic impulses, and are rather to be considered as ill-conditioned automata, than as vicious men. Of this latter class, some, from original constitution and early influences of the most degrading kind, seem altogether destitute of anything but a *brutal* nature; such ought to be treated as irresponsible beings, and, as such, restrained by external coercion from doing injury to society. But this class is small in proportion to that of individuals who *act* viciously, simply because they have never been led to *know* that any other course is open to them, or to *feel* any motives that might give them a different impulse. With these, the object should rather be to awaken the higher parts of the moral nature, "to find out the holy spot in every child's heart," and to develope habits of self-control in the manner just described, than to subjugate by external restraint; and the success which has attended this method, in the hands of those who have judiciously applied it, is sufficient evidence of its superiority; many of the most apparently-debased natures having been thus elevated to a grade, which it seemed at first impossible they could ever attain. From the *Satanic*, or positively and wilfully evil type of Human nature, in which the highest powers are turned to the worst account, we are thus conducted through the *brutal* or negatively evil type, towards that higher aspect of Humanity, which is presented by those who habitually keep before them the *Divine* ideal, and who steadily endeavour to bring their *whole nature* into conformity with it. This is *not* to be effected by dwelling *exclusively on any one* set of the motives already referred-to, as those which the truly religious man

keeps before his mind. Even the idea of Duty, *operating alone*, tends to reduce the individual to the subservience of a slave, rather than to induce in him that true mastery over himself, which consists in such a regulation of his emotions and propensities, that his course of duty becomes the spontaneous expression of his own higher nature; but it is a most powerful aid in the acquirement of that regulation, by the fixation of the thoughts and affections on "things on high," which is the best means of detaching them from all that is earthly and debasing. It is by the *assimilation*, rather than by the *subjugation*, of the Human Will to the Divine, that Man is really lifted towards God; and in proportion as this assimilation has been effected, does it manifest itself in the life and conduct; so that even the lowliest actions become holy ministrations in a temple consecrated by the felt presence of the Divinity. Such was the life of the Saviour; towards that standard it is for the Christian disciple to aspire.*

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840. *Of Sleep.* — It is a peculiar feature in the physiology of the Cerebral and Sensorial Ganglia, that their activity undergoes a periodical suspension, more or less complete; the necessity for this suspension arising out of the fact that the exercise of their functions is in itself destructive to their substance, so that, if this be not replaced by nutritive regeneration, they speedily become incapacitated for further use. In ordinary profound sleep, there is a state of complete unconsciousness, so far as *external* phenomena are concerned; no ordinary impressions upon the organs of sense being either felt or perceived; although an extraordinary impression, or even an habitual one upon which the attention has been previously fixed as that at which the slumberer is to awake himself (§ 843), occasions a renewal of sensorial activity. It is in this capability of being aroused by external impressions, that the chief difference lies between Sleep and the abnormal condition of Coma, whether this arise from the influence of pressure or effusion within the cranium, or be consequent upon the poisoning of the blood by narcotic substances, or follow a previous state of abnormal activity of the brain, such as delirium. Between these two conditions, however, every gradation may be seen; as in the gradually-increasing torpor which results from slow effusion within the cranium, the gradual loss of susceptibility to external impressions which is observed after an over-dose of a narcotic, and the intensification of ordinary sleep which is consequent upon extreme previous fatigue. It is a matter of doubt, however, whether the suspension of sensorial consciousness is equally complete as regards *internal* or Cerebral changes; for some are of opinion that, even in the most profound sleep, we still dream, although we may not remember our dreams; whilst others (and among these the Author would rank himself) consider that dreaming is a mark of imperfect sleep, and that, in profound ordinary sleep, the Cerebrum, as well as the Sensory Ganglia, is in a state of complete functional inactivity. When dreaming takes place, there is usually a less complete exclusion of sensory impressions, although the perceptive consciousness

* The careful study of the Epistles of St. Paul will show this to be the *dominant idea* of this Apostle's teachings. Under the name of "the law," he refers to the spirit of bondage or external coercion, which "was the schoolmaster to bring us to Christ;" whilst under the designation of "the Gospel" he obviously desires to express that spirit of freedom or internal spontaneity, which is the source of all that is truly noble in the Christian character.

may be entirely suspended; so that the course of the dream may be influenced by them, although the mind is not conscious of them as such (§ 828). If this be the true account of the case, we may consider that, in profound Sleep, the functional activity of the Cerebrum and of the Sensory Ganglia is alike suspended; that in Dreaming, the Cerebrum is partially active, and that the Sensorium is in such a condition of recipience for Cerebral impressions that the mind becomes directly conscious of them, whilst it only becomes conscious of impressions made upon the Organs of Sense, after their influence has been transmitted through it to the Cerebrum, and has been, as it were, reflected back by that organ. It is, in fact, by their influence upon the current of *ideas*, and not by their power of exciting *sensations*, that we recognize their operation under such circumstances.

841. The state of Sleep is one to which there is beyond doubt a *periodical* tendency; for, when the waking activity has continued for a considerable proportion of the twenty-four hours, a sense of fatigue is usually experienced, which indicates that the brain requires repose; and it is only under some very strong physical or moral stimulus, that the mental energy can be sustained through the whole cycle. In fact, unless some decidedly abnormal condition of the Cerebrum be induced by the protraction of its functional activity, Sleep will at last supervene, from the absolute inability of the organ to sustain any further demands upon its energy, even in the midst of opposing influences of the most powerful nature.* That the strongest voluntary determination to remain awake, is forced to give way to Sleep, when this is required by the exhaustion of nervous power, must be within the experience of every one; and the only way in which the Will can even retard its access, is by determinately fixing the consciousness upon some definite object, and resisting every tendency in the thoughts to wander from this. It does not appear to be of any consequence, whether this exhaustion be produced by the active exercise of volition, reflection, emotion, or simple sensation; still we find that the *volitional* direction of the thoughts, in a course different from that in which they tend spontaneously to flow, is attended with far more *effort* than the automatic activity of the mind (§ 823); whilst, on the other hand, the excess of *automatic* activity, whether as regards the intellectual operations or emotional excitement, tends to prevent sleep. This is particularly the case when the feelings are strongly interested; thus, the strong desire to work-out a result, or to complete the survey of a subject,

* Thus it is on record, that, during the heat of the battle of the Nile, some of the over-fatigued boys fell asleep upon the deck; and during the recent attack upon Rangoon, the Captain of one of the war-steamers most actively engaged, worn out by the excess of continued mental tension, fell asleep and remained perfectly unconscious for two hours, within a yard of one of his largest guns, which was being worked energetically during the whole period.—So even the severest bodily pain yields before the imperative demand occasioned by the continued exhaustion of the powers of the sensorial centres; thus Damiens slept upon the rack, during the intervals of his cruel sufferings; the North American Indian at the stake of torture will go to sleep on the least remission of agony, and will slumber until the fire is applied to awaken him; and the medical practitioner has frequent illustrations of the same fact.—That the continued demand for muscular activity is not incompatible with the access of sleep, is obvious from what has been already said of the persistence of the automatic movements in that condition (§ 726); it is well known that, previously to the shortening of the hours of work, factory children frequently fell asleep whilst attending to their machines, although well aware that they should incur severe punishment by doing so.

is often sufficient to keep up the intellectual activity as long as may be requisite (a state of restlessness, however, being often induced, which prevents the access of sleep for some time longer); so, again, anxiety or distress is a most frequent cause of wakefulness; and it is generally to be observed that the state of *suspense* is more opposed to the access of sleep, than the greatest joy or the direst calamity when certainty has been attained.* But although an excess of automatic activity is opposed, so long as it continues, to the access of sleep, yet it cannot be long protracted without occasioning an extreme exhaustion of nervous power, which necessitates a long period of tranquillity for its complete restoration. — But whilst the necessity for sleep arises out of the state of the nervous system itself, there are certain external conditions which favour its access; and these, in common parlance, are termed its predisposing causes. Among the most powerful of these is the *absence* of sensorial impressions; thus, darkness and silence usually promote repose; and the cessation of the sense of muscular effort, which takes place when we assume a position that is sustained without it, is no less conducive to slumber. There are cases, however, in which the *continuance* of an accustomed sound is necessary, instead of positive silence, the cessation of the sound being a complete preventive of sleep; thus it happens that persons living in the neighbourhood of the noisiest mills or forges, cannot readily sleep elsewhere. Such cases are referable, either to the influence of *habit*, which causes the attention of the individual to be more attracted by the suspension of the sound than by its continuance; or to the fact that the *monotonous repetition* of sensorial impressions is often more favorable to sleep than their complete absence. Thus it is within the experience of every one, that the droning voice of a heavy reader on a dull subject, is often a most effectual hypnotic; in like manner, the ripple of the calm ocean on the shore, the sound of a distant waterfall, the rustling of foliage, the hum of bees, and similar impressions upon the auditory sense, are usually favourable to sleep; and the muscular and tactile senses may be in like manner affected by an uniform succession of gentle movements, as we see in the mode in which nurses "hush-off" infants, or in the practice of gently rubbing some part of the body, which has been successfully employed by many who could not otherwise compose themselves to sleep. The reading of a dull book acts in the same mode through the visual sense; for the eyes wander on from line to line and from page to page, receiving a series of sensorial impressions which are themselves of a very monotonous kind, and which only tend to keep the attention alive in proportion as they excite interesting ideas.— In these and similar cases, the influence of external impressions would seem to be exerted in withdrawing the mind from the distinct consciousness of its own operations (the loss of which is the transition-state into that of complete unconsciousness), and in suspending the directing power of the Will. And this is the case even where the attention is in the first instance *voluntarily* directed to them; as in some of the plans which have been recommended for the induction of sleep, when there exists no spon-

* Thus it is a common observation that criminals under sentence of death sleep badly so long as they entertain any hopes of a reprieve; but as soon as they are satisfied that their death is inevitable, they usually sleep more soundly, and this even on the very last night of their lives.

taneous disposition to it. In other methods, the attention is fixed upon some internal train of thought, which, when once set-going, may be carried-on automatically; such as counting, or repeating a French, Latin, or Greek verb. In either case, when the sensorial consciousness has been once steadily fixed, the monotony of the impression (whether received from the Organs of Sense or from the Cerebrum) tends to retain it there; so that the Will abandons, as it were, all control over the operations of the mind, and allows it to yield itself up to the soporific influence. This last method is peculiarly effectual, when the restlessness is dependent upon some mental agitation, provided that the Will has power to withdraw the thoughts from the exciting subject, and to reduce them to the tranquillizing state of a mere mechanical repetition.

842. The access of Sleep is sometimes quite sudden; the individual passing at once from a state of complete mental activity to one of entire torpor. More generally, however, it is gradual; and various intermediate phases may be detected, some of which bear a close resemblance to the state of Reverie, whose peculiar nature has been already described (§ 824). The same may be said with regard to the transition from the state of Sleep to that of wakeful activity; for this also may be sudden and complete, although it usually consists of a succession of stages,—the complete consciousness of the individual's relation to the external world, and the power of directing his thoughts and actions to any subject about which he may be required to exert himself, being the last to be acquired. There may be a rapid alternation of these different states; the loss and recovery of the waking consciousness being many times repeated in the course of a few minutes, when the circumstances are such as to prevent the access of profound sleep by the recurrence of sensory impressions; as when a man on horseback, wearied from want of rest, lapses at every moment into a dozing state, from which the loss of the balance of his body as frequently and suddenly arouses him; or when a man going to sleep in a sitting posture, gradually loses the support of the muscles which keep his head erect, his head droops by degrees and at last falls forwards on his chest, and the slight shock thence ensuing partially arouses and restores his voluntary power, which again raises the head. Similar fluctuations occur in the sensory perceptions; and these may be often artificially induced by very simple means. "We find, for example, one condition of sleep so light, that a question asked restores consciousness enough for momentary understanding and reply; and it is an old trick to bring sleepers into this state, by putting the hand into cold water, or producing some other sensation, not so active as to awaken, but sufficient to draw the mind from a more profound to a lighter slumber. This may be often repeated, sleep still going on; but make the sound louder and more sudden, and complete waking at once ensues. The same with other sensations. Let the sleeper be gently touched, and he shows sensibility, if at all, by some slight muscular movement. A ruder touch excites more disturbance and motion, and probably changes the current of dreaming; yet sleep will go on; and it often requires a rough shaking, particularly in young persons, before full wakefulness can be obtained." * * * "It is certain that the faculties of sensibility and volition are often unequally awakened from sleep. The case may be stated, familiar to many, of a person sleeping in an upright posture, with the head falling over the breast;

in whom sensibility is suddenly aroused by some external impression, but who is unable, for a certain time, to raise his head, though the sensation produced by this delay of voluntary action is singularly distressing." These various cases, it is justly remarked by Dr. Holland,* depending severally on the intensity of sleep, and on the kind and degree of the external exciting causes, will be found to explain many of those so-called Mesmeric phenomena, which are offered to us under a widely different interpretation. And it may be here remarked, that among those intermediate states between sleep and waking, which either occur spontaneously, or can be induced in numerous individuals by very simple processes (§§ 825, 827), there are several which exhibit peculiarities that are not in themselves in the least degree less remarkable, than are those which are regarded with so much wonder by the uninformed observer, when induced by the asserted Mesmeric influence, and paraded as specimens of its powers (see § 845, *note*).

843. It is unquestionable that the supervention of Sleep may be promoted by the strong previous expectation of it; and this is true, not merely of ordinary sleep, but of the states of artificial Reverie and Somnambulism formerly described. Every one knows the influence of habit, not only in regard to 'time,' but also as to 'place and circumstance,' in predisposing to Sleep. Thus, the celebrated pedestrian Capt. Barclay, when accomplishing his extraordinary feat of walking 1000 miles in as many successive hours, obtained at last such a mastery over himself that he fell asleep the instant he lay down. And the sleep of soldiers, sailors, and others, who may be prevented from obtaining regular periods of repose, but are obliged to take their rest at short intervals, may be almost said to come at command; nothing more being necessary to induce it, than the placing the body in an easy position, and the closure of the eyes. It is related that the Abbé Faria, who acquired notoriety through his power of inducing somnambulism, was accustomed merely to place his patient in an arm-chair, and then, after telling him to shut his eyes and collect himself, to pronounce in a strong voice and imperative tone the word "dormez," which was usually successful. The Author has had frequent opportunities of satisfying himself, that the greater success which attends the 'hypnotic' mode of inducing somnambulism (§ 827) in the hands of Mr. Braid, its discoverer, than in that of others, partly lies in the mental condition of his subjects, who come to him for the most part under the confident expectation of its production, and are further assured by a man of very determined will that it *cannot* be resisted.† And it is one of the most curious phenomena of the 'biological' state (§ 825), that, in many subjects at least, sleep may be induced in a minute or less, by the positive assurance, with which the mind of the individual becomes possessed, that it *will* and *must* supervene. — The influence of previous mental states is yet more remarkable, in determining the effects produced upon the sleeper by different sensory impressions. The general rule is, that *habi-*

* See his excellent Chapter on 'Sleep,' from which the above extracts are taken, in his "Medical Notes and Reflections," and his "Chapters on Mental Physiology."

† A very amusing instance in which Sleep, having been previously induced by the ordinary 'mesmeric' and then by the 'hypnotic' processes, was brought on by the simple belief that a new process was being put in practice, will be found in the "Brit. and For. Med. Rev.," vol. xix. p. 477.

*ual* impressions of any kind have much less effect in arousing the slumberer, than those of a new or unaccustomed character. An amusing instance of this kind has been related to the Author, which, even if not literally true, serves extremely well as an illustration of what is unquestionably the ordinary fact. A gentleman who had taken his passage on board a ship of war, was aroused on the first morning by the report of the morning gun, which chanced to be fired just above his berth; the shock was so violent, as to cause him to jump out of bed. On the second morning he was again awoke, but this time he merely started and sat up in bed; on the third morning the report had simply the effect of causing him to open his eyes for a moment, and turn in his bed: on the fourth morning it ceased to affect him at all, and his slumbers continued to be undisturbed by the report, so long as he remained on board. It often happens that sleep is terminated by the *cessation* of an accustomed sound, especially if this be one whose monotony or continuous repetition had been the original inducement to repose. Thus, a person who has been read or preached to sleep, will awake, if his slumber be not very profound, on the cessation of the voice; and a naval officer, sleeping beneath the measured tread of the watch on deck, will awake if that tread be suspended.—In this latter case, the influence of the simple cessation of the impression will be augmented by the circumstance next to be alluded to, which has received too little attention from writers on this subject, but which is of peculiar interest both in a physiological and psychological point of view, and is practically familiar to almost every one. This is, that the awakening power of sensory impressions is greatly modified by our *habitual state of mind* in regard to them. Thus, if we are accustomed to *attend* to these impressions, and our perception of them is thus *increased* in acuteness, we are much more easily aroused by them, than we are by others which are in themselves much stronger, but which we have been accustomed to disregard. Thus, most sleepers are aroused by the sound of their own names uttered in a low tone, when it requires a much louder sound of a different description to produce any manifestation of consciousness. The same thing is seen in comatose states; a patient being often capable of being momentarily aroused by shouting his name into his ear, when no other sound produces the least effect. The following circumstance, communicated to the Author by the late Sir Edward Codrington, is a most apposite illustration of this principle. When a young man, he was serving as signal-lieutenant under Lord Hood, at the time when the French fleet was confined in Toulon harbour; and being desirous of obtaining the favourable notice of his commander, he devoted himself to his duty—that of watching for signals made by the look-out frigates—with the greatest energy and perseverance, often remaining on deck nineteen hours out of the twenty-four, with his attention constantly directed towards this one object. During the few hours which he spent in repose, his sleep was so profound, that no noise of an ordinary kind, however loud, would awake him; and it used to be a favourite amusement with his comrades, to try various experiments devised to test the soundness of his sleep. But if the word 'signal' was even whispered in his ear, he was instantly aroused, and fit for immediate duty.—The influence of habitual attention is shown as much in the effect produced by the cessation, as in that of the occurrence, of sensory

impressions. Thus in the case of the naval officer aroused by the suspension of the measured tread of the watch over his head, the knowledge possessed during the waking state, that this suspension is either an act of negligence which requires notice, or indicates some unusual occurrence, doubtless augments the effect which the discontinuance of the sound would of itself produce.—It is not requisite, however, that the sound should be one habitually attended-to during the hours of watchfulness; for it is sufficient if it be one on which the *attention has been fixed* as that at which the slumberer is to arouse himself. Thus the medical man, even in his first profound sleep after a fatiguing day's work, is aroused by the first stroke of the clapper of his night-bell; and to those who are accustomed to rise every morning at the sound of an alarum-clock, the frequency and regularity of the occurrence do not diminish, but rather increase, the readiness with which it produces its effect, provided that the warning be promptly obeyed. On this usually depends the efficiency of the awakening sound; if it be disregarded as a thing to which there is no occasion to give heed, it very soon ceases to produce any effect, the entire peal not being sufficient to awake the sleeper; whilst, on the other hand, the first stroke is enough to break the repose of him who is impressed with the effectual desire of profiting by the warning. And thus it may happen that, of two persons in the same room, either shall be at once aroused by a sound which produces no disturbance in the slumbers of the other. To this influence of previous impressions, whether habitual, or but once forcibly made, we are also to refer the spontaneous termination of the state of sleep at particular times, without any sensorial excitement from external impressions. Thus, many persons who are accustomed to rise at a particular hour, wake regularly at that hour, whether they have gone to rest early or late; so that the act of spontaneously awakening is no proof that the desirable amount of repose has been obtained. But what is more remarkable is, that many individuals have the power of determining, at the time of going to rest, the hour at which they shall rise, so as to awake from a profound sleep at the precise time fixed upon. In others, however, the desire to rise at a particular hour only induces a state of restlessness throughout the night, destroying the soundness of the slumbers: the individual awakes many times in the night, with the belief that the hour is past, and very possibly oversleeps it after all, the system being worn out by the need of repose.

844. The *Amount of Sleep* required by Man is affected by so many conditions, especially *age, temperament, habit,* and *previous exhaustion,* that no general rule can be laid down on the subject.—The condition of the *fœtus in utero* may be regarded as one of continual slumber; the apparatus of animal life being completely secluded from all stimuli which could arouse it into activity, whilst the energy of the organic functions is entirely directed to the building-up of the fabric. On its first entrance into the world, the infant continues to pass the greater part of its time in slumber; and this is particularly to be noticed in cases of premature birth, the seven months' child seeming to awake only for the purpose of receiving food, and giving but little heed to external objects, whilst even the eight months' child is considerably less alive to sensory impressions than one born at the full time. The excess of activity of the *constructive* over the *destructive* operations, which characterizes the whole period of

infancy, childhood, and adolescence (§§ 129—131), requires that a larger proportion of the diurnal cycle shall be passed in sleep (during which the former may be carried-on without hindrance), than is requisite when adult age has been attained, the two sets of changes being then balanced (§ 132); and the amount of sleep to which the system shows itself disposed, gradually diminishes from three-fourths to one-half, and from one-half to one-third, or even to one-quarter, of the twenty-four hours. It is to be noticed that the sleep of children or young persons is not only longer than that of adults, but is also more profound. On the other hand, as age advances, and the bodily and mental activity of the waking state decreases, a smaller amount of sleep suffices; or, if the slumber be protracted, it is usually less deep and refreshing. It may be noticed, however, that very old persons usually pass a large proportion of their time in sleep, or rather in a sort of heavy doze, especially after meals; as if, in consequence of the want of energy of their nutritive operations, a very long period of repose is necessary to repair the waste which takes place during their short period of activity.—In regard to the influence of *temperament*, it may be remarked that a plethoric habit of body, sustained by full diet, usually predisposes to sleep, provided that the digestive powers be in a vigorous condition; persons of this constitution frequently pass nine or ten hours in slumber, and maintain that they cannot be adequately refreshed by less. On the other hand, thin wiry people, in whom the 'nervous' temperament predominates, usually take comparatively little sleep, notwithstanding the greater activity of their nervous system when they are awake; but their slumber, while it lasts, is generally very deep. Persons of 'lymphatic' temperament, heavy passionless people, who may be said to live very slowly, are usually great sleepers; but this rather because, through the dulness of their perceptions, they are less easily kept awake by sensorial or mental excitement, than because they really require a prolonged cessation of activity. As they are half asleep during the waking state, so would it appear that the constructive operations must be far from active while they are asleep, so little do they seem restored by the repose. — The amount of sleep, *cæteris paribus*, required by individuals, is very greatly influenced by *habit;* and, contrary to what we might anticipate, we find that the briefest sleepers have usually been men of the greatest mental activity. Thus Frederick the Great and John Hunter are said to have only required five hours' sleep out of the twenty-four. General Elliot, celebrated for his defence of Gibraltar, is recorded not to have slept more than four hours out of the twenty-four. It may be doubted whether it would be possible for any one to sustain a life of vigorous exertion upon a smaller allowance than this; and the general fact is, that from six to eight hours of repose, out of every twenty-four, are required to keep the system of an adult in a state of healthful activity. The influence of habit may be brought to bear on the protraction, as well as on the abbreviation, of the usual period. Thus Quin, the celebrated actor, could slumber for twenty-four hours successively; and Dr. Reid, the metaphysician, could take as much food, and afterwards as much sleep, as were sufficient for two days.—It is needless to dwell upon the obvious fact, that, other things being equal, the amount of sleep required by man is proportional to the *amount of mental exertion* put forth during the waking hours; since this is an obvious result of

what has been laid down as the cause of the demand for sleep. It may be remarked, however, that we must not measure the *amount* of sleep by its *duration* alone; since its *intensity* is a matter of equal importance. The light slumber which is disturbed by the slightest sounds, cannot be as renovating as the profound sopor of those whom no ordinary noise will awake.

845. There are certain states of the Encephalic centres, in which there is an *entire absence of Sleep;* and this may continue for many days, or even weeks or months. Insomnia is, for instance, one of the characteristics of acute mania, and may also exist in various forms of monomania; it is usually, also, one of the symptoms of incipient meningeal inflammation; and it may constitute a specific disease in itself. In all these cases, however, the preponderance of the *destructive* processes over the *constructive* manifests itself, sooner or later, in the exhaustion of the mental and bodily powers. Thus mania, when prolonged or frequently occurring, subsides into dementia; and, if it continue for any length of time, is sure to be followed by a great sense of wretchedness and prostration, frequently accompanied by continual restlessness. Such effects, too, in a less aggravated degree, result from habitual *deficiency* of sleep; whether this result from emotional excitement, which keeps repose at bay, or from a voluntary determination to keep the intellect in activity. This is a very common occurrence among industrious students, who, with a laudable desire for distinction, allow themselves less than the needed quantum of repose. Headache, tension, heat, throbbing, and various other unpleasant sensations in the head, give warning that the brain is being overtasked; and if this warning be not taken, sleep, which it was at first difficult to resist, becomes even more difficult to obtain; a state of general restlessness and feverish excitement are induced; and if, in spite of this, the effort be continued, serious consequences, in the form of cerebral inflammation, apoplexy, paralysis, fever, insanity, or loss of mental power, more or less complete, are nearly certain to be induced. Some individuals can sustain such an effort much longer than others, but it is a great mistake to suppose that they are not equally injured by it; in fact, being possessed with the belief that they are not suffering from the exertion, they frequently protract it until a sudden and complete prostration gives a fearful demonstration of the cumulative effects of the injurious course in which they have been persevering. Those, consequently, who are earlier forced to give way, are frequently capable of accomplishing more in the end.—In regard to the degree of *protraction* of sleep which is consistent with a healthy state of the system in other respects, it is difficult to speak with certainty. Of the numerous well-authenticated instances on record,* in which sleep has been continuously prolonged for many days or even weeks, it is enough here to state that they cannot be regarded as examples of natural sleep; the state of such persons being more closely allied to hysteric coma. An unusual tendency to ordinary sleep generally indicates a congested state of the brain, tending to apoplexy; and it has been stated that apoplexy has been actually induced by the experimental attempt to ascertain how large a proportion of the diurnal cycle might be spent in

* Such, for example, as that of Samuel Chilton ("Phil. Trans.," 1694), and that of Mary Lyall ("Trans. of Roy. Soc. of Edinb.," 1818).

leep. Thus, on either side, inattention to the dictates of Nature, in espect to the amount of sleep required for the renovation of the system, ecomes a source of disease, and should therefore be carefully avoided.*

* *On Mesmerism.*—It appears to the Author that the time has now come, when a tolerably efinite opinion may be formed regarding a large number of the phenomena commonly ncluded under the term "Mesmerism." Notwithstanding the exposures of various pretenders, which have taken place from time to time, there remains a considerable mass of phenomena, which cannot be so readily disposed of, and which appear to him to have as just a title to the attention of the scientific Physiologist, as that which is possessed by any other class of well-ascertained facts.

Passing over, for the present, the inquiry into the manner in which these effects may be induced, the Author may briefly enumerate the principal phenomena which he regards as having been veritably presented in a sufficient number of instances, to entitle them to be considered as genuine and regular manifestations of the peculiar bodily and mental condition under discussion :—

1. A state of complete *Coma* or perfect insensibility, analogous in its mode of access and departure to that which is known as the "Hysteric Coma," and (like it) usually distinguishable from the Coma of Cerebral oppression by a constant twinkling movement of the eyelids. In this condition, severe surgical operations may be performed, without any consciousness on the part of the patient; and it is not unfrequently found that the state of torpor extends from the Cerebrum and Sensory Ganglia to the Medulla Oblongata, so that the respiratory movements become seriously interfered-with, and a state of partial asphyxia supervenes.

2. A state of *Somnambulism* or Sleep-waking, which may present all the varieties of the natural Somnambulism, from a very limited awakening of the mental powers, to the state of complete Double Consciousness, in which the individual manifests all the ordinary powers of his mind, but remembers nothing of what has passed when restored to his natural waking state. This state of Somnambulism, in the form which it commonly takes, is characterised by the facility with which the thoughts are directed into any channel which the observer may desire, by the principle of "suggestion;" and by the want of power, on the part of the Somnambulist, to apply the teachings of ordinary experience to the correction of the erroneous ideas which are thus made to occupy the mind. In these particulars, this condition closely corresponds with that of the Artificial Somnambulism or 'hypnotism' of Mr. Braid (§ 827); and the only peculiarity in its phenomena which can be regarded as at all essential, consists in the special relation which is affirmed to exist between the mesmerizer and his 'subject.' Now in regard to the existence of this *rapport*, it is specially note-worthy, that it was not discovered until long after the practice of Mesmerism had come into vogue, having been unknown to Mesmer himself and his immediate disciples; and that its phenomena have only acquired constancy and fixity, in proportion as its (supposed) laws have been announced and received as established. The history of Mesmerism, candidly and philosophically analysed, affords abundant evidence in proof of this position; but the best guarantee of its truth is drawn from the results obtained by the numerous Mesmerizers, who have begun to experiment for themselves without any knowledge of what they were to expect, and who have produced a great variety of remarkable phenomena, without having ever discovered this *rapport;* and yet have obtained immediate evidence of it, when once the idea has been put into their own minds, and thence into those of their 'subjects.' It is quite easy to understand, that if the mind of the 'subject' be so yielded-up to that of the mesmerizer, as to receive and act-upon any impression which the latter forces-upon or even suggests-to it, the notion of this peculiar relation is as easily communicable as any other, and may exert a complete domination over the 'subject,' through the whole of the sleep-waking state. Thus the commands or suggestions of the mesmerizer meet with a response which those of no other individual may produce; in fact, the latter usually seem to be unheard by the somnambule, simply because they are not related to the dominant impression,—a phenomenon of which the experience of natural somnambulism is continually presenting examples. And further, it being a fact, that individuals of what may be termed the susceptible constitution, have brought themselves, by the habit of obedience, into complete subjection to the expressed or understood will of some other party, even in the waking state, without any mesmeric influence whatever, it is not at all difficult to understand how such a habit of attending to the operator, and to him alone, should be peculiarly developed in the state of Somnambulism, in which the mind seems to have lost its self-acting power, and to be the passive recipient of external impressions. And the same explanation applies to the other phenomena of this *rapport;* such as its establishment with any bystander, by his joining hands with the mes-

merizer and the somnambule; for, as already shown (§ 827), it is quite sufficient that the somnambule should be previously possessed with the idea that this new voice will thus be audible to her, and that she must obey its behests, for it to produce all the same effects upon her as that of the mesmerizer had previously done. In all the *successful* experiments of this kind which the Author has seen, this previous idea *was* entertained, both by mesmerizer and somnambule; but in by far the larger proportion of cases which have fallen under his notice, and especially when the subjects of them were not *habitués* of the mesmeric *séances*, the phenomena of this class could not be made to show themselves, the consciousness of the somnambule not being limited to the mesmerizer or to those *en rapport* with him, but being equally extended to all around her.

3. A frequent phenomenon of this condition, and one which has its parallel in Natural Somnambulism, is a remarkable *Exaltation of one or more of the Senses*, so that the individual becomes susceptible of influences, which, in his natural condition, would not be in the least perceived. The Author has witnessed a case in which such an exaltation of the sense of Smell was manifested; and in the same case, as in many others, there was a similar exaltation of the sense of Temperature. The exaltation of the Muscular Sense, by which various actions that ordinarily require the guidance of vision, are directed independently of it, is a common phenomenon of the 'mesmeric' with various other forms of artificial as well as of natural Somnambulism. The Author has repeatedly seen Mr. Braid's 'hypnotized' subjects write with the most perfect regularity, when an opaque screen was interposed between their eyes and the paper, the lines being equidistant and parallel; and it is not uncommon for the writer to carry back his pen or pencil to dot an *i* or cross a *t*, or make some other correction in a letter or word. Mr. B. had one patient who would thus go back and correct with accuracy the writing on a whole page of note-paper; but if the paper was moved from the position it had previously occupied on the table, all the corrections were on the *wrong* points of the paper as regarded the *actual* place of the writing, though on the *right* points as regarded its *previous* place; sometimes, however, he would take a fresh departure, by feeling for the upper left hand corner of the paper, and all his corrections were then made in their right positions, notwithstanding the displacement of the paper.—To the extraordinary exaltation of one or more of the senses, which is a characteristic of this state, may fairly be attributed a great number of the phenomena which have been supposed to indicate a peculiar and mysterious influence exerted by the mesmerizer over his subject; since the latter will be far more receptive of 'suggesting' impressions, than an ordinary bystander would suppose possible. And it is to be borne in mind, that the concentration of the attention upon these may often give them a far greater significance to the individual, than they possess for others; this, it seems likely, is especially the case in regard to tones of voice, emphasis of manner, &c., when questions are propounded.

4. The Muscular system may also be excited to action in unusual modes, and with unusual energy. Notwithstanding the fallacy of many of the cases of Cataleptic rigidity which have been publicly exhibited, the Author is satisfied, from investigations privately made, of the possibility of artificially inducing this condition. A slight irritation of the muscles themselves, or of the skin which covers them,—as by drawing the points of the fingers over them, or even wafting currents of air over the surface,—is sufficient to excite the tonic muscular contraction, which may continue in sufficient force to suspend a considerable weight, for a longer period than it could be kept up by any conceivable effort of voluntary power. But these are phenomena which are quite as well displayed in Artificial Somnambulism induced in other ways, as they are in the 'mesmeric' state; and do not afford, therefore, any more than the preceding, the slightest indication of the speciality of the latter, or the least proof of any extraneous influence exerted over the 'subject.'

5. Various effects, it is asserted, may be produced upon the *Organic Functions* by 'Mesmeric' influence; and it is on account of this agency, that it claims to be admitted as a directly-curative agent. It will be hereafter shown, however, that effects of a precisely similar kind may be produced in other forms of Artificial Somnambulism, by simply fixing the attention on the part; and that the same may be done, even in the ordinary waking state, in certain subjects who can be worked-up to the requisite pitch of confident expectation (See CHAP. XVIII.).

The foregoing are the principal phenomena of the 'Mesmeric' state, in regard to which the Author feels his mind made up. He does not see why any discredit should be attached to them, since they correspond in all essential particulars with those of states, which naturally or spontaneously occur in many individuals, and which he has had opportunities of personally observing, in cases in which the well-known characters of the parties placed them above suspicion. When the facility with which the mind of the Somnambulist is played-on by suggestions (conveyed either in language, or through other sensations which excite asso-

iated ideas), and the absence of the corrective power ordinarily supplied by past experience, re duly kept in view, many of the supposed "higher phenomena" of Mesmerism may be ccounted for, without regarding the patient on the one hand as possessed of extraordinary owers of divination, or on the other as practising a deception. Thus, bearing in mind hat Somnambulism is an acted dream, the course of which is governed by external impressions, it is easy to understand how the subject of it may be directed by leading questions to nter buildings which he has never seen, and to describe scenes which he has never witnessed, without any intentional deceit. The love of the marvellous so strongly possessed y many of the witnesses of such exhibitions, prompts them to grasp-at and to exaggerate the coincidences in all such performances, and to neglect the failures; and hence reports re given to the public, which, when the real truth of them is known, prove to have been the results of a series of guesses, the correctness of which is in direct relation to the amount of guidance afforded by the questions themselves. In like manner, the manifestations of the excitement of the "phrenological organs" seem to depend upon the conveyance of a suggestion to the patient, either through his knowledge of their supposed seat, or through the anticipations expressed by the by-standers. Many instances are recorded, in which the intention has been stated of exciting one organ, whilst the finger has been placed-upon or pointed-at another; and the resulting manifestation has always been that which would flow from the former. It does not hence follow that intentional deception is being practised by the Somnambulist; since the condition of mind already referred-to, causes it to respond to the suggestion which is most strongly conveyed to it.

In regard to the alleged powers, which are said to be possessed by many Somnambulists, of reading with the eyes completely covered, or of discerning words inclosed in opaque boxes, or of giving an account of what is taking place at a distance, all coming under the general term *Clairvoyance*, the Author need only here express his conviction that no case of this description has ever stood the test of a searching investigation.

With respect to the modes in which the 'Mesmeric' Somnambulism is induced, it appears to him that they are all referable to those states of *monotony of sensory impressions*, and of *expectation*, to which reference has been already made as among the most potent of the predisposing causes of conditions allied to Sleep (§ 843). It is asserted by Mesmerizers, that they can induce the 'Mesmeric' state from a distance, without the least consciousness on the part of their 'subjects' that any influence is being exerted on them,—an assertion, which, if true, would go far to establish the existence of a force altogether *sui generis*, capable of being transmitted from one individual to another. Here, however, as in regard to the 'higher phenomena' last adverted-to, the Author feels compelled to state that no evidence of an affirmative kind has yet been adduced, which can be in the least degree satisfactory to a scientific inquirer, who duly appreciates all the sources of fallacy to which these occurrences are open. Among these, the state of expectation on the part of the 'subject' is the most important; since this has been shown, by repeated experiments, to be of itself quite sufficient to induce the state, when the 'subject' has been led to entertain it; whilst, if it be *altogether* wanting, the most powerful mesmeric influence, so far as the Author's personal knowledge extends (and on this subject, he must be excused for trusting rather to the results of his own investigations, than to the statements of other individuals, however trustworthy on ordinary matters), has always failed. A very striking instance of this kind is contained in the "Brit. and For. Med. Rev.," vol. xix. p. 478, in an Article to which the Author may refer as on the whole expressing (although not written by himself) his own opinions on this curious and interesting subject; strengthened as these are by much subsequent inquiry into the phenomena of 'Hypnotism' and 'Electro-Biology,' the attentive and scientific study of which will tend, he feels assured, to eliminate the true from the false in Mesmerism, more effectually than any other method of procedure. Much has been done by the inquiries of Mr. Braid of Manchester, who discovered the 'hypnotic' mode of inducing Artificial Somnambulism, and who has carefully studied the phenomena of the hypnotic state; and the Author feels it due to that gentleman further to mention, that very soon after the publication of the first edition of Baron Reichenbach's researches on Odyle, Mr. Braid discovered their true explanation, and exhibited to the Author many of the 'odylic' phenomena, as the results of *suggestion* in certain individuals, whom he had discovered to have the power of voluntarily inducing a state of Abstraction or artificial reverie, closely corresponding to what is now termed the Electro-Biological condition.

On the whole subject of Sleep and its allied states, as well as on that of Cerebral Physiology generally, the Author would strongly recommend his readers to study Dr. Holland's "Chapters on Mental Physiology;" in which they will find a most valuable and suggestive collection of facts and doctrines, based upon an extended practical experience, and brought to bear particularly upon the more difficult and recondite portions of the inquiry.

### 6. *Of the Sympathetic System, and its Functions.*

846. That collection of scattered but mutually-connected ganglia and nerves, which altogether constitute what is now generally designated the *Sympathetic System*, may be ranged under the following groups:—1. The isolated ganglia and nerves in immediate connection with the viscera, which seem to be the chief centres of the system; these form three principal plexuses, the *cardiac*, the *solar*, and the *hypogastric*. 2. The double chain of *prevertebral* ganglia, with connecting cords, which lies in front of the Vertebral column, and communicates on the one hand with the spinal nerves, and on the other with the before-named plexuses. Under this head we should probably rank the minute cranial ganglia, which are situated in the neighbourhood of the Organs of Sense, and in immediate connection with the branches of the 5th Pair that proceed to them; these are the *ophthalmic*, *otic*, *spheno-palatine*, and *submaxillary* ganglia. 3. The ganglia on the posterior roots of the Spinal nerves; under which head we are probably to rank not only the Gasserian ganglion of the 5th Pair, but also the ganglia near the roots of the Pneumogastric and Glosso-pharyngeal nerves. — The trunks of the Sympathetic are made-up of different orders of fibres; some of these being derived from the Cerebro-Spinal system, whilst others have their central termination in the vesicular matter of the Sympathetic ganglia themselves.—These last, which are all of the 'gelatinous' kind (§ 339),* are most abundant in the great visceral plexuses; but they may be traced from the prevertebral ganglia into the spinal nerves, where they are reinforced by the fibres which have their centres in the ganglia of the posterior roots. Thus it appears that the Cerebro-Spinal and Sympathetic systems interpenetrate one another; each having its own series of ganglionic centres and of trunks connected with them; but each system transmitting its own fibres into the trunks of the other, and even ganglia of the Sympathetic being dispersed among the Cerebro-spinal tubules.

847. It is in virtue of the connections of the Sympathetic with the Cerebro-spinal system, that the parts which are solely supplied with nerves from the former, are capable of transmitting sensory impressions to the Sensorium, and of receiving motor impulses from the Encephalic centres. It is true that, under ordinary circumstances, these parts are insensible, that is, impressions made upon them do not travel onwards through the Spinal Cord to the Encephalon; but their sensibility is acutely manifested in morbid states, in which the impressions seem to be propagated further than usual, in virtue of their greater potency. That it is the office of the ganglia on the roots of the Spinal nerves to "cut off sensation," that is, to prevent the further transmission of sensory impressions, is an old doctrine; and there seems much reason to believe that this may be effected by the free communication between one fibre and another, which is established through the vesicular substance of a ganglion, so that the whole force of ordinary impressions on the nerve-fibres is lost in diffusion among the rest of their contents. The same

* It must be carefully borne in mind, that, although the proper Sympathetic fibres are all gelatinous, yet that the Cerebro-Spinal system contains gelatinous fibres of its own, which are very abundant in some parts.

principle seems to apply to the motor fibres; for there are cases which show that when fibres obviously belonging to Cerebro-spinal nerves pass through Sympathetic ganglia, they do not so rapidly or so surely transmit motor impulses, as when they have no such relation to ganglia.*—Although it is not easy to obtain definite evidence of the influence of the Sympathetic system on Muscular Contraction, since this influence is extinguished within a short time after death, yet it has been established by the elaborate researches of Prof. Valentin † that contractions of the various muscular parts supplied by the three great visceral plexuses may be excited by irritation applied to their nerves and ganglia. But he has further shown, that the same effects may be produced by irritating the Prevertebral ganglia, the cords of communication with the Spinal nerves which have been sometimes termed the *roots* of the Sympathetic, and the roots of the Spinal nerves themselves. It results from his inquiries, that, although any particular division of the Sympathetic nerve must be regarded as extremely complex in its relations, deriving its motor fibres from many different sources, the ultimate distribution of these fibres is sufficiently simple, so that each organ is definitely supplied from a certain part of the cerebro-spinal axis. But the fibres proceeding from the roots of the cerebro-spinal nerves do not pass into the nearest organs, being transmitted through three or more of the prevertebral ganglia of the Sympathetic before reaching their ultimate destination; thus the motor fibres of the cardiac plexus are principally derived from the cervical portion of the Spinal Cord, those of the solar plexus from the thoracic region, and those of the hypogastric plexus from the dorsal region. No experimental evidence has yet been afforded, that the *proper fibres of the Sympathetic System* have any power of exciting muscular contraction, or that its ganglia can serve as centres of reflex action to the organs which they supply; on the contrary, it is quite certain that the ganglia in the posterior roots of the Spinal nerves have no such endowment. And as all the facts which have been supposed to indicate the existence of such a power, may be otherwise explained in accordance with our fundamental doctrine (§§ 432-3, 497-8), it seems fair to conclude that the motor power of the Sympathetic system, — which is chiefly exercised on the muscular substance of the heart and the walls of the blood-vessels, on the muscular coat of the alimentary canal and of the larger gland-ducts that open into it, and on the muscular walls of the genito-urinary organs,— is entirely derived from the Cerebro-Spinal system. In no instance, however, can the Will exert any influence over the movements of these parts; they are strongly affected by emotional states of mind; and they frequently seem to respond to impressions made on remote organs. One of the most remarkable cases of a definite motion uniformly excited through the Sympathetic system, is the *dilatation of the pupil*, which, after many imperfect attempts to determine its source, has now been shown by the experiments of MM. Budge and Waller to be effected through the cervical portion of the Sympathetic. For whilst irritation of the trunk of the cervical Sympathetic by means of the magneto-electric machine, produces dilatation of the pupil with just as much certainty as irritation of the

* See Messrs. Kirkes and Paget's "Handbook of Physiology," 2nd edit., p. 471.

‡ "De Functionibus Nervorum Cerebralium et Nervi Sympathici," Bernæ, 1839; lib. ii. cap. 2.

3rd pair determines its contraction, section of that trunk occasions permanent contraction of the pupil, the action of the 3rd pair being no longer antagonized. But this, like the other motor powers of the Sympathetic, is dependent upon the Spinal Cord; for magneto-electric irritation of any part of it between the first cervical and the sixth dorsal vertebra produces the same effect, which is most decided when the irritation is applied to the central part of this region. It appears from other experiments, that the fibres by which this movement is effected pass through the Gasserian ganglion, and are distributed to the eye by the ophthalmic branch of the 5th Pair.*

848. If, then, the sensori-motor endowments of the Sympathetic trunks be restricted to those fibres which are really Cerebro-Spinal in their origin or termination, it remains to inquire what are the functions of the *true* Sympathetic fibres, whose vesicular centres lie in the ganglia of the Sympathetic System. Upon this point we can only surmise; but there appears strong ground for the conclusion, that the office of these fibres is to produce a direct influence upon the chemico-vital processes concerned in the Organic Functions of nutrition, secretion, &c.; an influence which, although not essential to the performance of each separate act, may yet be required to harmonize them all together, and to bring them into connection with mental states. That the Nervous System does exert such an agency will be hereafter shown (CHAP. XVIII.); and reasons will there be assigned for regarding the Sympathetic fibres as its principal, if not as its sole channel.

### 7. *General Recapitulation, and Pathological Applications.*

849. In summing-up the views which have been propounded in this Chapter, with regard to the functions of the Nervous System, it will be advantageous to follow the reverse order to that which has been previously adopted, and to proceed from above downwards, instead of from below upwards.

I. The entire *Nervous System*, like other organs of the body, possesses vital endowments peculiar to itself, in virtue of which it tends to respond in a determinate manner to impressions made upon it; its several parts being distinguished by the results of impressions acting upon each respectively. In so far, then, as any part of the Nervous System merely reacts upon impressions which are made upon it, we must regard its operations as *automatic;* and this as much when they give rise to Psychical changes, as when they manifest themselves in evoking Muscular movements, or in modifying the processes of Nutrition and Secretion.

II. But the automatic actions of most parts of the Nervous System are subject, more or less completely, to the domination of the *Will*, a power which is purely Psychical, and of which we know nothing but what we learn from our own direct consciousness of its exercise. The power of the Will is the *greatest* over the automatic actions of the *highest* portions of the Nervous Centres, which are concerned in psychical changes; whilst it has the *least* influence over the automatic actions of those lower centres, which minister solely to the functions of the bodily organism.

* See "Gazette Médicale," 1851, Nos. 41, 44.

III. The *Cerebrum* is the material organ, through whose instrumentality all the processes of Thought are carried on. These processes are first called into activity by impressions conveyed to the vesicular matter of the Cerebral surface, by *ascending* nerve-fibres which proceed to it from the Sensory Ganglia; and the influence of that activity is re-transmitted to the Sensory Ganglia by a converse set of *descending* fibres.* There is much reason to consider that, until such re-transmission has taken place, the consciousness is not so affected by Cerebral changes as to give to the results of these changes a *psychical* character; for the central Sensorium appears to stand in precisely the same anatomical and physiological relation to the vesicular matter of the Cerebral surface, that it does to the vesicular matter of the Retina or other peripheral expansions of the Sensory nerves; and there is strong analogical ground for the belief, that the process by which the Mind is rendered conscious of changes in the Cerebrum, is performed by the same instrumentality as that by which it is made acquainted with impressions on the Organs of Sense. And this view is confirmed by the fact, that automatic changes may take place in the Cerebrum, without any consciousness on our own parts, the results of which, when we are at last made conscious of them, correspond with those that we ordinarily attain by processes whose successive steps excite as many successive states of consciousness.

IV. These Cerebral changes, then, acting downwards upon the Sensorium, give rise to those changes in our consciousness which we designate as *Mental Processes.* These processes,— called into activity by Sensorial changes,—ranging from the simple act of Perception to the highest operations of Intellectual power,— consisting also in the play of Fancy and Imagination, and including those active states known as Passions, Emotions, Moral Feelings, Sentiments, &c., — must be regarded as essentially *automatic* in their nature, and as the manifestations of the 'reflex' activity of the Cerebrum; since we have abundant evidence that they can take place without any self-direction on the part of the individual, who, whilst his Will is in abeyance, is in the condition of an animal entirely governed by Instinct. There is, however, far less of uniformity in these 'reflex actions' of the Cerebrum, than we observe in those reflex actions of other parts of the Nervous System, which give rise to the movements ordinarily designated as instinctive; this diversity seems partly attributable to differences in the *original* constitution of different individuals; but it is certainly due in great part to differences in the *acquired* constitution of the organ, arising out of the mode in which it has been habitually exercised,— this being dependent, on the one hand, on the circumstances in which the individual has been placed; and, on the other, on the use he has made of his Will.

V. When the power of the *Will* has been duly cultivated, it acquires so complete a domination over the automatic actions of the Cerebrum, that it can regulate the course of thought and the degree of emotional excite-

* The structural distinctness of these two sets of fibres must be admitted to be hypothetical, and it is improbable that any anatomical evidence can ever be attained, by which the hypothesis may be established. But all the analogy of the afferent and efferent fibres throughout the body, is opposed to the idea that the same fibres can serve both purposes. Whatever may be thought of their structural distinctness, however, there can be no reasonable doubt of the transmission of nerve-force in the two directions above indicated.

ment; intensifying some of these actions, and repressing others, by determinate efforts directed with a special purpose. Its power is so far limited, however, — that it can only *select* from the objects which spontaneously present themselves to the consciousness, those which it desires to retain and employ; and has no direct power of bringing before the mind any object not actually present to it. Hence it is, that, whilst we have an almost unlimited power of turning to the best account the endowments we possess, by strengthening our intellectual powers, expanding our higher emotional tendencies, and bringing the lower under wholesome restraint, we cannot, by any effort of the Will, introduce *new* elements into our psychical nature.*

VI. The power of the Cerebrum to call-forth muscular movements, is entirely exerted through the intermediation of the Cranio-Spinal Axis upon which it is superimposed; no motor fibres directly issuing from the Cerebrum itself. These movements, when directly determined by the Will, may be designated as *Volitional;* when they are involuntarily excited by states of passion, feeling, &c., of which they are the external expressions, they are distinguished as *Emotional;* and when they are prompted, in the absence of any volitional exertion, by dominant ideas, they may be termed *Ideational.* In each case, the nerve-force transmitted downwards from the Cerebrum appears to produce the very same state of activity in the Sensori-motor apparatus, as that which may be directly excited in it by impressions transmitted from the Organs of Sense; and thus the same instrumentality serves for all classes of movements, voluntary and involuntary; the difference in their character being solely referable to the diversity of their primal source.

VII. The Cerebrum being the instrument of all psychical activity, we must regard its action as disordered in every state in which that activity is perverted. The first degree of departure from the normal state, is usually shown in the want of Volitional control over the sequence of thought; and this may exist merely to the extent of giving the reflex power of the organ too great a predominance, so that trains of thought and states of feeling succeed each other automatically, and all the actions of the individual are simply the expressions of these. Such is the mental state which exists in *Reverie* and in *Somnambulism,* natural or induced; the principal varieties in these states being traceable to the relative degree of influence of ideas already fixed in the mind, and of external suggestions, in determining the course of thought. It is to be remarked in regard to these conditions, however, that they are generally characterized by a somewhat inactive state of the Cerebrum, so that the changes

* No one has ever *acquired* the creative power of genius, or *made himself* a great artist or a great poet, or *gained by practice* that peculiar insight which characterizes the original discoverer; for these gifts are mental instincts or intuitions, which may be developed and strengthened by due cultivation, but which can never be generated *de novo.* It not unfrequently happens, however, that the gift lies dormant, until some appropriate impression excites it into activity. Such is especially the case with regard to the higher Moral Feelings, which are too often so completely repressed by the degrading influences under which the youthful mind expands itself, that they might be considered as altogether wanting. Though dormant, however, they are rarely extinct, and may be called into activity by appropriate management. It has been by faith in this principle, and by skill in its application, that those have achieved the greatest success, who have recently devoted themselves to the much-needed work of Juvenile Reformation. (See "Reformatory Schools," by Mary Carpenter.)

in the state of consciousness are not rapid, but such as do occur are coherent.* In *Dreaming*, *Delirium*, and the artificial Delirium of *Intoxication*, on the other hand, with a like absence of the directing and restraining power of the Will, there is a greater and more irregular activity in the Cerebral operations, the ideas presenting themselves in far more rapid succession, and possessing a less perfect mutual coherence.

VIII. The foregoing states are closely allied to *Insanity;* many forms of which may be almost exactly paralleled by transient states of Somnambulism, whilst others are but a modification of Delirium. A deficiency or entire absence of the controlling power of the Will is the common feature of all forms of this disorder, and is frequently its first manifestation. But Insanity is essentially constituted by excessive, deficient, or perverted activity of some one or more of the automatic tendencies, and must thus be regarded as consisting in a disordered action of the Cerebrum. This may be traced to a great variety of causes, which may be classified in different ways, according as we take their *own nature* or their *modus operandi* as the basis of our arrangement. Thus it is unquestionable that in a large proportion of cases of settled Insanity, there is an impairment of the due *Nutrition* of the Cerebrum; and this, which is often an hereditary defect, may arise *de novo*, like abnormal changes in the nutrition of other parts (CHAP. XI.), from deficiency or perversion in the formative power of the tissue, or from an imperfect supply or from an altered character of its pabulum. Of the influence of deficient or perverted formative power in the tissue, we have examples in the Insanity resulting from mechanical injuries of the brain, and from excessive 'wear' of the organ by forced activity. Of the effects of deterioration in the character of the blood, we have illustrations in the Insanity that is often linked-on with constitutional diseases of which such deterioration is a marked feature, and in that which is so frequent a consequence of habitual excess in the use of Alcoholic liquors. These conditions may exist in combination;† and it is, probably, by such a combination, that many of the 'moral causes' of Insanity operate. For there can be little doubt that Emotional excitement, from its immediate relation to Nerve-force (§ 805), has a direct influence on the formative capacity of the Cerebrum; whilst, on the other hand, we know that it has so great an influence over the Organic functions, that it can produce very serious alterations in the

* In most forms of induced Somnambulism, it appears as if the mental activity is only sustained by external prompting, all *spontaneous* activity being suspended; for the 'subject' continually relapses into a state of unconsciousness, and does not pass from one subject to another unless induced to do so by 'leading questions.' In some cases of this kind, however, as well as in all those forms of natural Somnambulism in which the individual acts on the spontaneous promptings of his own thoughts, the mental state is one of continuous activity; but it is obvious that its operations are slow, and are very limited in their nature.

† Thus *Delirium tremens*, which may be regarded as a form of temporary Insanity, essentially consisting in perverted and imperfect nutrition of the Cerebrum, seems ordinarily dependent conjointly upon the excessive and irregular activity to which the organ has been previously forced, and on the alteration of the normal character of the Blood produced by the habitual presence of Alcohol in its current; but it is well known that Delirium tremens *may* occur as the result of other agencies that primarily depress the nutritive powers without perverting the blood; such as excessive depletion, the shock of severe injuries, or extreme cold. In either case, however, the indications of treatment are the same; namely, to induce sleep, whereby the irregular activity of the organ may be completely suspended, and its due nutrition restored; and to correct what may be faulty in the condition of the blood.

condition of the Blood (CHAP. XVIII.) But without any serious perversion of the *nutrition* of the Cerebrum, its *action* may be disturbed, either by the presence of some toxic agent in the Blood, or by functional disturbance in other parts of the Nervous system. The delirium of Intoxication is, whilst it lasts, a true Insanity; and it ceases because the poison is eliminated from the system. But there are many cases in which there is a continual production of a poison within the system, which deranges the normal train of mental action so long as the blood is tainted by it; the indication of treatment is here obviously to check this production, and to depurate the blood; and when this has been effectually accomplished, the healthy action of the Brain is immediately restored, which would not have been the case if its nutrition had been seriously impaired. Most persons have experienced the extreme depression of spirits and incapacity for mental exertion, which are consequent upon certain derangements of the digestive function, and especially upon disorder of the biliary apparatus; and it is unquestionable that many forms of Insanity, in which extreme dejection is a prominent symptom, but which may also include intellectual delusions, are solely dependent upon this cause. The functional disturbance of the Cerebrum induced by the irregular action of other parts of the Nervous System, is a part of the Etiology of Insanity which has been as yet but very little attended-to, but which deserves a careful study. Numerous examples of it are furnished by certain peculiar forms of disordered Mental action, which are connected with 'hysterical' states of the female system, especially mutability and irritability of temper and disposition to deceit;* but we are probably also to refer to this cause, in part at least, those very distressing states of mind, which arise out of disorders in the sexual apparatus of the male, or even from irritation of neighbouring parts.†—It frequently happens that agencies of both classes contribute to the result; some long-continued defect of nutrition (very often arising from hereditary constitution) serving as the 'predisposing cause,' whilst some violent mental emotion, or depravation of the blood by some noxious matter, acts as the 'exciting cause;' the two conjointly producing that effect, which neither would singly have brought about.

IX. Without any Mental perversion, however, indicative of structural or functional disorder of the Cerebrum, there may exist a partial severance of its connection with the Sensori-motor apparatus; so that it cannot receive sensory impressions from particular organs or parts of the body, or call-forth muscular movement in respondence to volitional determinations or to emotional excitement. Or, again, there may be a weakening of Voluntary power over the muscles in general, whilst they still remain amenable to the stimulus of Emotion; and in such cases, as might be expected, the influence of sensory impressions in directly exciting muscular movements is obviously manifested.‡ Of the precise pathological

* See Dr. Laycock's "Treatise on the Nervous Diseases of Women," in which these *sympathies* are fully dwelt on.

† See M. Lallemand's "Treatise on Spermatorrhœa," translated by Mr. McDougal.—In some of the cases recorded by M. Lallemand, the most extreme mental depression was engendered by the presence of ascarides in the rectum!

‡ Of this curious state, the following example was communicated to the Author, about four years since, by his friend Mr. Noble.—"Mr. R. æt. 41, of a sanguine nervous temperament, a married man, and father of several children, the youngest being but two months old,

alterations which give rise to these peculiar conditions (which frequently manifest themselves in regard to particular groups of muscles, such as those of vocalization), nothing whatever is known. — Nearly allied to this state is that which gives rise to the 'jactitating convulsion,' interfering with volitional movement, which is known as *Chorea*. On the physiological views here advocated, this disease must be regarded as consisting essentially in a diminution of the power of the Will (exerted through the Cerebrum) over the muscular apparatus, concurrently with an augmented and perverted activity of the Sensori-motor centres. That its special seat is at the summit of the Cranio-Spinal axis, where it comes into connection with the Cerebrum, would appear from several considerations, particularly from the interruption of voluntary power, the aggravation of the movements by emotion, and their cessation during sleep; the two latter facts being inconsistent with the idea that the proper Spinal centres are essentially involved, although they are frequently affected coincidently or subsequently. The choreic convulsion is occasionally hemiplegic; and it sometimes gives place to paralysis, which is seldom complete, however, and may usually be cured by appropriate treatment. This disorder appears generally traceable to a state of imperfect nutrition, dependent upon a depraved and perhaps a poisoned state of the blood, rather than on any organic lesion.* Not unfrequently the defect of nutrition seems to act as the 'predisposing cause' of the disease; the attack being immediately traceable to mental emotion.† — *Stammering* may be regarded as a sort of Chorea, affecting the muscles of Voice (§ 943).

x. The *Sensory Ganglia*, collectively constituting the *Sensorium*, may be regarded as the most essential part of the Encephalon; since we find them fully developed in animals which scarcely possess a rudiment of a Cerebrum, and presenting the same relative condition to the latter in the

exhibited the following symptoms, first experienced in a slight degree about five years ago, and since then having become much aggravated, the climax having apparently been attained about two years ago.—There was partial paralysis of voluntary motion upon the left side, exhibiting under ordinary circumstances the customary phenomena; but with this peculiarity, —that although Volition was comparatively powerless, any incident excitor impression of an unusual character, by exciting, as it were, Consensual action, would give effect to the voluntary intention; thus, when the affected arm was raised by another to a certain height, the patient was unable by mere volition to elevate it still more; but if the hand were smartly struck or blown upon either by himself or by another, movement of a rapid character would at once ensue, and that too in conformity with the volitional effort. Upon inquiry, moreover, it appeared that any unwonted impression upon the internal as well as the external senses was capable of leading to a realization of the effort vainly attempted by the mere will, hence by accomplishing the commencement of a *run* or *trot* by aid of some undue impression, he could go on; he stated, on the case being proposed, that if, in utter paralysis of voluntary power over the muscles, a hundred-pound note were suddenly placed before his vision, and he were told that on seizing it the same should be his, he should at once be equal to the requisite effort.—When in health, Mr. R. stated that he had excellent controlling power over the Emotions, but that now the pleasure and the pain attendant upon their excitation were exalted, and the consensual phenomena quite irresistible; and on further inquiry it appeared that, in the matter of laughing and crying, he exhibited very much of the hysterical condition. In early life, Mr. R. had been what is called a free liver; both in regard to women, and to alcoholic stimulants."

* See Dr. Todd's Lumleian Lectures 'On the Pathology and Treatment of Convulsive Diseases' in the "Medical Gazette," April 20 and 27, 1849.

† A remarkable number of cases of Chorea were admitted into the Bristol Infirmary within a few weeks after the memorable Riots of 1833.

early embryo of Man. They directly receive the nerves proceeding from the organs of Special Sense, each pair of which has its own distinct ganglionic centre; and they receive also, through the (so-called) Crura Cerebri, the nerves of 'common sensation,' whose ganglionic centre appears to lie in the Thalami Optici. They give-off a large number of motor fibres, which, descending through the Crura Cerebri, are distributed, with the fibres proceeding from the Spinal ganglia, through the various motor trunks, to the muscular system generally.* On the other hand, by one set of the radiating fibres of the Cerebral substance, they transmit sensorial impressions upwards to the vesicular surface of the Hemispheres; whilst conversely, by its descending fibres, they receive the impressions transmitted downwards from the Cerebral ganglia; and they thus constitute the medium by which alone the Cerebrum communicates with the Organs of Sense on the one hand, and with the muscular apparatus on the other. — The Sensory Ganglia must be collectively regarded as forming the organ through whose instrumentality the Mind is rendered conscious of impressions made on the Organs of Sense; and reasons have been advanced for the belief, that it also serves as the instrument whereby the Consciousness is affected by Cerebral changes, which, in so far as they take place independently of the Will, are the cause and not the consequence of Mental activity. There is no reason to think that the Sensorium has in itself any higher function than that of impressing the consciousness of the individual; this impression on the consciousness, when made by an external agency operating through the sensory nerves, is that which is known as *Sensation;* but, when produced by Cerebral changes, it constitutes *Ideation.* With the states of consciousness termed Sensations are associated the simple *feelings* of pleasure and pain, the seat of which is obviously sensorial; and similar feelings, associating themselves with those states of consciousness termed Ideas, give to them an Emotional character, and become the sources of those *motives* by which the determination of conduct made by the Reason is in great part guided.

XI. The 'reflex action' of the Sensory Ganglia, which proceeds from their own independent activity, is manifested in all those instinctive or automatic movements, which are excited through sensations, and which may hence be designated as *consensual* or *sensori-motor.* These actions are but little noticed, in Man, in the active state of his Cerebrum; for the automatic movements on which the maintenance of his organic functions is immediately dependent, are provided-for by the Spinal centres; and the purposes which are answered in the lower animals by the higher order of Instinctive actions, are worked-out in him by the Intelligence. There is, however, a large group of *secondarily-automatic* movements, which, though originally determined by the Will, are brought by habit so far under the direct influence of sensations, that they continue, whilst prompted and guided by the latter, after the Will has ceased to act.— The operation of the Sensory Ganglia in Man is usually subservient to

* The doctrine previously advocated (§ 701), that there is an actual continuity of fibres between the Sensorial centres and the roots of the Spinal Nerves, has lately received very important confirmation from the elaborate researches of Dr. Turck on the alterations produced in the Spinal Cord by Hemiplegia originating in intra-cranial lesion. See his Memoir 'Uber secondäre Erkrankung einzelner Rückensmarksstränge und ihrer Fortsetzungen zum Gehirne,' in "Denkschriften der kaiserlichen Academie der Wissenschaften," Wien, 1851.

that of the Cerebrum; for the influence of Sensational changes, being propagated upwards to that organ, excites further changes in it; these, reflected downwards to the Sensori-motor centres, become the sources of ideational or of emotional movements; and the determining power of the Will, in producing volitional movements, is exercised through the same channel. It is a remarkable indication of the participation of the Sensorial centres even in volitional movements, that these cannot be executed save with the concurrence of *guiding sensations.* The extent to which the Sensory Ganglia may act as independent centres of action, is seen in cases in which the functions of the Cerebrum are entirely in abeyance. This may happen through congenital defect, as in some cases of complete Idiocy, especially among the Cretins of the first degree, who spend their whole time in basking in the sun or sitting by the fire (experiencing merely sensorial pleasure), and who show no higher traces of intelligence, than is evinced by their going, when excited by hunger, to the places where they have been accustomed to receive food. It may occur, too, as a consequence of disease or injury. Of this we have an example in a case mentioned by Dr. Rush, of a man who was so violently affected by some losses in trade, that he was deprived almost instantly of his mental faculties; he did not take the slightest notice of anything, not even expressing a desire for food, but merely receiving it when it was put into his mouth; a servant dressed him in the morning, and conducted him to a seat in his parlour, where he remained the whole day, with his body bent forwards and his eyes fixed on the floor; in this state he continued for five years, and then recovered completely and rather suddenly. The well-known case of the sailor who suffered for more than a year from depressed fracture of the skull, and was at last restored to his normal condition by the elevation of the depressed bone (which was effected by Mr. Cline), affords another illustration of the same suspension of cerebral activity, without the loss of sensorial power; this man passed the period between the accident and the operation in a condition very similar to that of the subject of the preceding case; and after his recovery, the whole intervening space was a perfect blank to his recollection. The most remarkable example of this condition, however, yet put on record, is a case which occurred a few years ago under the observation of Mr. Dunn,* of whose excellent account an abridgment is here given, for the sake of illustrating the nature of a purely *sensorial* and *instinctive,* as distinguished from an *intelligent* existence, and the gradual nature of the transition from the one to the other.† A very similar condition presents

* "Lancet," Nov. 15 and 29, 1845.

† The subject of this case was a young woman of robust constitution and good health, who accidentally fell into a river and was nearly drowned. She remained insensible for six hours after the immersion; but recovered so far as to be able to give some account of the accident and of her subsequent feelings, though she continued far from well. Ten days subsequently, however, she was seized with a fit of complete stupor, which lasted for four hours; at the end of which time she opened her eyes, but did not seem to recognize any of her friends around her; and she appeared to be utterly deprived of the senses of hearing, taste, and smell, as well as of the power of speech. Her mental faculties seemed to be entirely suspended; her only medium of communication with the external world being through the senses of sight and touch, neither of which appeared to arouse *ideas* in her mind, though respondent *movements* of various kinds were excited through them. Her vision at short distances was quick; and so great was the exaltation of the general sensibility upon the surface of the body, that the slightest touch would startle her; still, unless she was

itself, as the result of the complete exhaustion of Cerebral power, in those extreme forms of Dementia, or rather Amentia, which are frequently consequent upon repeated attacks of Mania, or a long succession of Epileptic

touched, or an object or a person was so placed that she could not help seeing the one or the other, she appeared to be quite lost to everything that was passing around her. She had no notion that she was at home, nor the least knowledge of anything about her; she did not even know her own mother, who attended upon her with the most unwearied assiduity and kindness. Wherever she was placed, there she remained during the day. . . . . . Her appetite was good; but having neither taste nor smell, she ate alike indifferently whatever she was fed with, and took nauseous medicines as readily as delicious viands. All the automatic movements unconnected with sensation, of which the spinal cord is the instrument, seemed to go on without interference; as did also those dependent upon the sensations of sight and touch; whilst the functions of the other ganglia, together with those of the cerebral hemispheres, appeared to be in complete abeyance. The analysis of the facts stated regarding her ingestion of food seems to make this clear. She swallowed food when it was put into her mouth; this was a purely automatic action, the reception by the lips being probably excited by sensation, whilst the act of deglutition, when the food is carried within reach of the pharyngeal muscles, is excited without the necessary concurrence of sensation. She made no spontaneous effort, however, to feed herself with the spoon; showing that she had not even that simple idea of helping herself, which infants so early acquire. But after her mother had conveyed the spoon a few times to her mouth, and had thus caused the muscular action to become associated with the sensorial stimulus, the patient continued the operation. It appears, however, to have been necessary to repeat this lesson on every occasion; showing the complete absence of memory for any idea, even one so simple and so immediately connected with the supply of the bodily wants. The difference between an *instinct* and a *desire or propensity*, heretofore dwelt on (§ 772), is here most strikingly manifested. This patient had an instinctive tendency to ingest food; as is shown by her performance of the actions already alluded to; but these actions required the stimulus of the present sensation, and do not seem to have been connected with any notion of the character of the object *as food;* at any rate, there was no manifestation of the existence of any such notion or idea, for she displayed no *desire for food* or drink in the absence of the objects, even when she must have been conscious of the uneasy sensations of hunger and thirst. The very limited nature of her faculties, and the *automatic* life she was leading, appear further evident from the following particulars. One of her first acts on recovering from the fit had been to busy herself in picking the bed-clothes; and as soon as she was able to sit up and be dressed, she continued the habit by incessantly picking some portion of her dress. She seemed to want an occupation for her fingers, and accordingly part of an old straw bonnet was given to her, which she pulled to pieces of great minuteness; she was afterwards bountifully supplied with roses; she picked off the leaves, and then tore them into the smallest particles imaginable. A few days subsequently, she began forming upon the table, out of these minute particles, rude figures of roses and other common garden flowers; she had never received any instructions in drawing.—Roses not being so plentiful in London, waste paper and a pair of scissors were put into her hands; and for some days she found an occupation in cutting the paper into shreds; after a time these cuttings assumed rude figures and shapes, and more particularly the shapes used in patchwork. At length she was supplied with proper materials for patchwork; and after some initiatory instruction, she took to her needle and to this employment in good earnest. She now laboured incessantly at patchwork from morning to night, and on Sundays and week-days, for she knew no difference of days; nor could she be made to comprehend the difference. She had no remembrance from day to day of what she had been doing on the previous day, and so every morning commenced *de novo.* Whatever she began, that she continued to work-at while daylight lasted; manifesting no uneasiness for anything to eat or drink, taking not the slightest heed of anything which was going on around her, but intent only on her patchwork. She gradually began, like a child, to register ideas and acquire experience. This was first shown in connexion with her manual occupation. From patchwork, after having exhausted all the materials within her reach, she was led to the higher art of worsted-work, by which her attention was soon engrossed as constantly as it had before been by her humbler employment. She was delighted with the colours and the flowers upon the patterns that were brought to her, and seemed to derive special enjoyment from the harmony of colours; nor did she conceal her want of respect towards any specimen of work that was placed before her, but immediately threw it aside if the arrangement displeased her. She still had no recollection from day to day what she had

seizures. And it is also worth notice, that the "picking at the bed-clothes," which is so frequently seen towards the close of life, is a purely consensual movement, the performance of which is an indication of the

done, and every morning began something new, unless her unfinished work was placed before her; and after imitating the patterns of others, she began devising some of her own. The first *ideas* derived from her former experience, that seemed to be awakened within her, were connected with two subjects which had naturally made a strong impression upon her; namely, her fall into the river, and a love-affair. It will be obvious that her pleasure in the symmetrical arrangement of patterns, the harmony of colours, &c., was at first simply *sensorial;* but she gradually took an interest in looking at pictures or prints, more especially of flowers, trees, and animals. When, however, she was shown a landscape in which there was a river, or the view of a troubled sea, she became intensely excited and violently agitated, and one of her fits of spasmodic rigidity and insensibility immediately followed. If the picture were removed before the paroxysm had subsided, she manifested no recollection of what had taken place; but so great was the feeling of dread or fright associated with water, that the mere sight of it in motion, its mere running from one vessel to another, made her shudder and tremble; and in the act of washing her hands they were merely placed in water. From this it may be inferred that simple *ideas* were now being formed; for whilst the actual sight or contact of moving water excited them by the direct sensorial channel, the sight of a picture containing a river or water in movement could only do so by giving rise to the notion of water. From an early stage of her illness she had derived evident pleasure from the proximity of a young man, to whom she had been attached; he was evidently an object of interest when nothing else would rouse her; and nothing seemed to give her so much pleasure as his presence. He came regularly every evening to see her, and she as regularly looked for his coming. At a time when she did not remember from one hour to another what she was doing, she would look anxiously for the opening of the door about the time he was accustomed to pay her a visit; and if he came not, she was fidgetty and fretful throughout the evening. When by her removal into the country she lost sight of him for some time, she became unhappy and irritable, manifested no pleasure in anything, and suffered very frequently from fits of spasmodic rigidity and insensibility. When, on the other hand, he remained constantly near her, she improved in bodily health, early associations were gradually awakened, and her intellectual powers and memory of words progressively returned. We here see very clearly, as it appears to us, the composite nature of the emotion of affection. At first, there was simple pleasure in the presence of her lover, excited by the gratification which former association had connected with the *sensation.* Afterwards, however, it was evident that the pleasure became connected with the *idea;* she *thought* of him when absent, expected his return (even showing a power of measuring time when she had no memory for anything else), and manifested discomfort if he did not make his appearance. Here we see the true *emotion*, namely, the association of pleasure with the *idea;* and the manner in which the *desire* would spring out of it. The desire in her then condition, would be inoperative in causing voluntary movement for its gratification; simply because there was no intellect for it to act upon. Her mental powers, however, were gradually returning. She took greater heed of the objects by which she was surrounded; and on one occasion, seeing her mother in a state of excessive agitation and grief, she became excited herself, and in the emotional excitement of the moment suddenly ejaculated, with some hesitation, "What 's the matter?" From this time she began to articulate a few words; but she neither called persons nor things by their right names. The pronoun "this" was her favourite word; and it was applied alike to every individual object, animate and inanimate. The first objects which she called by their right names were wild flowers, for which she had shown quite a passion when a child; and it is remarkable that her interest in these and her recollection of their names should have manifested itself at a time when she exhibited not the least recollection of the "old familiar friends and places" of her childhood. As her intellect gradually expanded, and her *ideas* became more numerous and definite, they manifested themselves chiefly in the form of *emotions;* that is, the chief indications of them were through the signs of pleasure and pain. The last were frequently exhibited, in the attacks of insensibility and spasmodic rigidity, which came on at the slightest alarm. It is worth remarking that these attacks, throughout this remarkable period, were apt to recur three or four times a day, when her eyes had been long directed intently upon her work; which affords another proof how closely the emotional cause of them must have been akin to the influence of sensory impressions, the effects of the two being precisely the same.—The mode of recovery of this patient was quite as remarkable as anything in her history. Her health and bodily strength seemed completely

torpor that has supervened upon the functional activity of the Cerebrum.

XII. It is the *Sensorium* that is primarily, and (it may be) solely affected, in the state of *Coma;* which differs from ordinary Sleep only in the completeness of the suspension of the functional activity of the Sensory Ganglia. This suspension not merely prevents impressions transmitted from the organs of sense, from affecting the consciousness as Sensations; but it also interposes the same obstacle to that mental recognition of Cerebral changes, which, when the Sensorium is closed to the outer world, constitutes the state of Dreaming; and thus the comatose subject is not merely insensible to external impressions, but is cut off from all perception of self-existence. There seems reason to believe, that, in the simpler forms of Coma, such as we frequently meet with in hysterical subjects, there is no perversion of the functions of the Cerebrum; for we observe that, if the insensibility suddenly supervene in the midst of a sentence which is being uttered by the patient (a circumstance of no uncommon occurrence), the series of words is taken up and completed the moment that the coma passes off, the patient being unconscious of the interruption; showing that there is none of that *confusion* of the Intellect which marks Cerebral disorder. In a large proportion of cases, however, it is obvious, from the order in which the symptoms manifest themselves, that the Cerebrum is affected, as well as the Sensorial centres; of this the best evidence is afforded by the phenomena of alcoholic intoxication, and the agency of narcotic poisons; and where Coma results from pressure within the cranium, this must act alike upon the Cerebrum and the Sensorium. Of the causes which induce the state of Coma, there are many which, when operating in smaller quantity, or in less intensity, produce delirium. This is particularly the case with the whole group of truly narcotic poisons; and is not merely true of those which are introduced as such from external sources, but also with regard to those which are generated within the body. We have another illustration of it in the Coma of mere exhaustion, which is frequently preceded by delirium that is clearly attributable to nothing else than a deficient supply of blood. Still, we must not regard Coma as always indicating a more advanced state of morbid

re-established, her vocabulary was being extended, and her mental capacity was improving, when she became aware that her lover was paying attention to another woman. This idea immediately and very naturally excited the emotion of jealousy; which, if we analyse it, will appear to be nothing else than a painful *feeling* connected with the *idea* of the faithlessness of the object beloved. On one occasion this feeling was so strongly excited, that she fell down in a fit of insensibility, which resembled her first attack in duration and severity. This, however, proved sanatory. When the insensibility passed off, she was no longer spell-bound. The veil of oblivion was withdrawn; and, as if awakening from a sleep of twelve months' duration, she found herself surrounded by her grandfather, grandmother, and their familiar friends and acquaintances, in the old house at Shoreham. She awoke in the possession of her natural faculties and former knowledge; but without the slightest remembrance of anything which had taken place in the interval, from the invasion of the first fit up to the present time. She spoke, but she heard not; she was still deaf, but as she could read and write as formerly, she was no longer cut off from communication with others. From this time she rapidly improved, but for some time continued deaf. She soon perfectly understood by the motion of the lips what her mother said; they conversed with facility and quickness together, but she did not understand the language of the lips of a stranger. She was completely unaware of the change in her lover's affections which had taken place in her state of second consciousness; and a painful explanation was necessary. This, however, she bore very well, and has since recovered her previous bodily and mental health.

hange, than that which occasions Delirium; for it stands to some forms f delirium, in the same light in which ordinary sleep stands to the vaking state, being the repose which is required for reparation after a tate of excessive mental activity. In fact, the profound sleep which ucceeds a protracted period of severe bodily or mental exertion, is often lmost comatose, as regards the degree in which the subject of it is insensible o external stimuli. The same may be stated with great probability of he coma which is consequent upon 'concussion' of the brain; for this nay be regarded as a period of slow regeneration, during which the effects of the injury are being repaired by the nutritive processes; and ny attempt to arouse the patient prematurely is far more likely to be njurious than beneficial, tending especially to increase the violence of the subsequent reaction.

XIII. It is, as we have seen, in the Sensorial centres, that those lesions are most commonly found, which give rise to hemiplegic *Paralysis.* There can be little doubt that this form of paralysis is usually attributable to some structural disorganization of the nervous substance, produced by hæmorrhage, softening, &c. Still, this, like other forms of partial paralysis, may be *toxic*, depending rather upon the condition of the blood, than upon that of the nervous tissue. Of such toxic influence, we have a remarkable example in the peculiar local paralysis induced by the presence of Lead in the system; and there seems much reason to believe that some of the Hysterical forms of paralysis (as well as of convulsive disorders) are of toxic origin. There are many instances, too, in which paralysis, like convulsion, seems to depend upon some injurious influence propagated from the nerves of some other part.—Although it is in Hemiplegia that we have the most distinct evidence of disorder of the Encephalic centres, yet paralysis of any one part of the body may proceed from Encephalic lesion; and even some forms of Paraplegia seem traceable to disorders of the Cerebrum and Sensory Ganglia.*

XIV. We seem entitled to consider the Sensory Ganglia as the primary seat of that combination of loss of sensibility with spasmodic movements, which essentially constitutes *Epilepsy.* This is marked by the peculiar sensorial phenomena which usually precede the paroxysm; by the obliteration of consciousness, which is its prominent symptom; and by the peculiarity of the spasmodic contractions, which are *clonic* (or alternating with relaxation) instead of being *tonic* (or persistent), and which correspond with those that may be induced by artificial stimulation of this portion of the Encephalic centres (§ 738). The disordered action, however, manifestly extends itself to the Cerebrum; for a maniacal paroxysm frequently occurs in connection with the epileptic attacks; the attacks themselves are sometimes preceded, and very commonly followed, by considerable confusion of the intellect; the disease is seldom long persistent without impairing the memory and the control of the will over the mental operations; and in cases of long standing, the power of the Cerebrum appears to be almost entirely destroyed. There is very considerable diversity, on the other hand, in regard to the nature and intensity of the muscular convulsion; and there seems reason to think that when the morbid influence is determined downwards into the Motor apparatus, the

* For much valuable information on the different forms of Paralysis, see Dr. Gull's Gulstonian Lectures 'On the Nervous System' in the "Medical Times," 1849.

Cerebrum escapes with a less serious impairment of its powers, since the destruction of the intellectual power occurs more surely where the fits are accompanied by much mental disturbance or stupor, than where the convulsive character predominates.—One of the most remarkable phenomena of Epilepsy is its tendency to periodic recurrence, with a more or less complete return to the normal state in the interval. This fact of itself seems to indicate that the disease cannot be fairly attributed to those obvious lesions of structure, which are sometimes coincident with it, and which, as Dr. Todd has justly remarked, are rather the signs of the altered nutrition brought on by any cause which creates frequent disturbance of the actions of the brain, than the causes of that disturbance; for the influence of such lesions, if manifested at all (and it is remarkable what an extent of disorganization *may* take place without any obvious indication), would be rather continuous than intermitting. It is quite certain, on the other hand, that death *may* occur from Epilepsy, without any appreciable lesion. It may be considered, also, as a well-established fact, that the epileptic paroxysm may be induced either by an insufficient supply, or by depravation of blood; of this we have examples in the epileptiform convulsions brought on by excessive hæmorrhage in parturient women, in the epileptiform paroxysm induced by asphyxia (especially by strangulation), and in poisoning by hydrocyanic acid, the phenomena of which, in the lower animals especially, so closely simulate those of the genuine disease, that they may be designated as an artificial epilepsy. These and many other facts in the etiology of the disease, very strongly point to a disordered condition of the blood as its primal source; this acting either by altering the nutrition of the Encephalic centres, or by perverting their action, or in both modes conjointly, as in the case of Insanity (VIII.). According to the theory advocated by Dr. Todd, a continual mal-nutrition of certain parts of the Encephalon occasions a gradually-increasing disturbance of their polar state; and this, when it has attained a certain measure of intensity, manifests itself in the epileptic paroxysm, just as a Leyden jar, when charged with electricity to a certain state of tension, gets rid of the disturbance of equilibrium by the "disruptive discharge."* The fact must not be disregarded, however, that when a state of mal-nutrition of the Nervous System has been established by causes which affect the condition of the Blood, the Epileptic paroxysm may be induced by some eccentric or peripheral irritation, such as worms in the intestinal canal, the pressure of teeth in the eruptive stage of development against the capsule or the gum, &c.; neither cause being sufficient when acting alone. Hence, although the paroxysms may be suspended, and the disease apparently cured, by the removal of the peripheral source of irritation (as by the expulsion of the worms, or the complete eruption of the teeth), the liability to it still remains, as is shown by the renewal of the paroxysms whenever any fresh irritation may arise. It is very important, therefore, not to rest satisfied with local treatment in such cases; but to have recourse to measures adapted to produce a general invigoration of the system.†

* See Dr. Todd's 'Lumleian Lectures' in the "Medical Gazette," May 18, 1849; and the "Brit. and For. Med. Chir. Rev.," Jan. 1850, pp. 24—33.

† The Author does not think it necessary here to devote any space to the examination of Dr. M. Hall's pathological theory of Epilepsy, which makes it depend upon spasmodic con-

XV. The *Spinal Axis* (including the *Medulla Oblongata*) forms a continuous series of ganglionic centres, which are connected by afferent and efferent nerve-trunks with the several segments of the body; but these centres are enveloped in white or fibrous strands, which not only connect the various segmental divisions with each other, but also, there seems good reason to believe, establish a continuous connection between the Nerve-roots and the Sensorial-centres. The independent activity of the Spinal centres is seen in the various reflex movements which are performed after they have been cut-off from all connection with the Encephalon; and of these reflex movements, there are certain definite groups, which are subservient to the functions of Respiration, Deglutition, Defecation, &c. In so far as these are performed by the Spinal Cord alone, without the participation of the Sensorium, they do not involve any affection of the consciousness; and as the separation of the Spinal Cord from the Sensorium effectually prevents the impression which excites the reflex movement from exciting sensation at the same time, we know that sensation cannot be necessary to the movement; hence this class of actions is best distinguished as *excito-motor*, in contradistinction to the *sensori-motor* in which Sensation necessarily participates. Putting aside, however, those actions which are subservient to the Organic functions, and which are performed in the state of full integrity and activity of the nervous system, we find that the reflex power of the Spinal Cord is only distinctly manifested when that organ is detached from the Encephalon; for in its normal state it serves as little else than the channel through which impressions are transmitted upwards to the Sensorium, and thence to the Cerebrum, and through which motor impulses are propagated downwards from these centres to the muscles. For the actions of the Spinal Cord are placed in subordination to the control of the Cerebrum, in every particular as to which they can be, without detriment to the welfare of the system generally; so that we find excitor impressions, which are quite competent to evoke reflex actions if they are prevented from travelling beyond the Cord, losing their power to do so when they are discharged (so to speak) into the Sensorium; whilst even the movements of Respiration, Defecation, &c., which do not require the participation of the Cerebrum in their ordinary performance, can be to a certain extent controlled by the Will.

XVI. In the various classes of *Convulsive* diseases in which the consciousness is *not* affected, we have manifestations of the perverted activity of the Spinal Cord as a whole, or of certain of its segments.—Of the distinct forms or combinations of which this class of disorders is composed, *Tetanus* is one of the most interesting and instructive. This disease essentially consists in an undue excitability of the whole series of Spinal Ganglia; so that very slight impressions produce violent and extensive reflex actions, the disturbance of nervous polarity induced by the impression, radiating (as it were) through the whole Cord, and affecting nerve-fibres that proceed from each of its different segments; and when this state is fully established, convulsive actions may proceed from purely *centric* irritation, no excitor impression being required to originate them.

pression of certain muscles of the neck, producing compression of the veins and congestion of the cerebrum; since he considers that the fallacies of this theory have been already sufficiently pointed out by Dr. Todd (loc. cit.).

Such a state may be induced by various causes, among the most prominent of which are, on the one hand, those which affect the nutrition of the Cord, and, on the other, those which call it into disordered action, by altering the relations which the blood bears to it as the exciting fluid of the nervous battery. That which is termed the idiopathic form of the disease seems traceable to mal-nutrition of the Cord, consequent upon impoverishment or depravation of the blood; that, on the other hand, which is produced by the introduction of Strychnia into the blood, is dependent upon the peculiar potency of this substance in determining a wrong action of the Spinal centres, for which it seems to have an elective affinity, in the same way that alcohol and opium have for the encephalic. With regard to the traumatic form of Tetanus, it is impossible to say with certainty whether the peculiar condition of the Spinal Cord be determined, as in the preceding case, by the introduction of a poison into the blood, through some morbid action taking place in the wound; or whether the disturbance of the usual equilibrium be consequent upon the propagation of a morbid influence directly from the injured nerve-trunk to the Spinal centres, without any participation of the Circulating System in this extension of the mischief. Whichever be the true account of it, this much is certain, that when the Tetanic state of the Spinal Cord is once fully established, nothing is gained by removal of the injured part; and powerful sedative remedies alone possess any influence in restraining the paroxysms. The Cerebral apparatus is entirely unaffected in this disorder; but the nerves of deglutition are usually those first influenced by it; those of respiration, however, being soon affected, as also those of the trunk in general.—The condition termed *Hydrophobia* is nearly allied to that of traumatic Tetanus, differing chiefly in the mode in which the cranio-spinal axis is affected. The irritable state of the nervous centres obviously results from the introduction of a poison into the blood; and here the early removal of the wounded part is very desirable as a means of prevention; although, when the poison has once begun to operate on the centres, it is of no use. The muscles of respiration and deglutition are, as in Tetanus, those spasmodically affected in the first instance; but there is this curious difference in the mode in which they are excited to action,—that, whilst in Tetanus the stimulus operates through the Spinal Cord (either centrally, or by being conveyed from the periphery), in Hydrophobia it is often transmitted from the ganglia of Special Sense, or even from the Cerebrum; so that the sight or sound of fluids, or even the idea of them, occasions—equally with their contact, or with that of a current of air—the most distressing convulsions.—Many forms of that protean malady, *Hysteria*, are attended with a similar irritability of the Nervous Centres; but there is this remarkable difference in the two cases, that the morbid phenomena of Hysteria, whilst they often simulate those of Chorea, Tetanus, Hydrophobia, Epilepsy, &c., are evidently dependent upon a state of the system of a much less abnormal character. The absence of any structural lesion, and even of any serious impairment of the nutrition, of the parts of the Nervous System which are the sources of the actions in question, is proved by the length of time during which the severest forms of them may exist without permanently-serious consequences, and by the suddenness with which the several forms of them give place one to another, or pass-off altogether. The strange combina-

tions, moreover, which they occasionally present, remarkably distinguish them from the more settled forms of the diseases which they simulate.* The clinical history of Hysteria, then, would lead us to suppose that the convulsive action depends rather upon some state of the blood which alters its relation to the nervous tissue as its exciting fluid, than upon any such change in the nutritive supply which it affords, as would induce a more permanent disorder in the system. Taking all the phenomena, however, into account, there seems much reason to think that a general excitability of the nervous system, such as is only an exaggeration of that which is characteristic of the female sex, is induced by some defect of Nutrition, comparatively permanent in its nature; whilst the particular forms of perverted action are determined either by some toxic agent in the blood, slight variations in which may give it a selective power for one part or another of the Nervous Centres, or by irritation of the peripheral nerves. Among the sources of imperfect nutrition, leading to undue excitability of the nervous system, and thus acting as a 'predisposing cause,' it seems probable that a gouty diathesis is one of the most frequent; † whilst among the exciting causes, some irregular action of the sexual apparatus is among the most common, though it would not be

* Thus, the Author has known an obstinate case of Hysteric disorder, in which at one period attacks of the most complete Opisthotonos coexisted with perfect Coma; at another period, the Coma recurred alone; then, again, there was Trismus, lasting for five consecutive days, without any other spasmodic action or loss of sensibility; this sometimes alternated with fits of Yawning, in which the jaw was held open for half an hour together; at another period, the convulsions had more of the Epileptic character, the face being distorted, and the limbs agitated, concurrently with a state of Coma, but without laryngismus; with this alternated fits of Laryngismus, without insensibility, and occurring during the *ex*piratory movement; whilst during the whole of this succession, there was Paralysis of the extensor muscles of both lower extremities, with paroxysms of the most violent and prolonged Cramp in one of them. (See § 325 note.) The mental phenomena were almost equally strange; for a state of almost Maniacal excitement often came on suddenly, and ceased no less abruptly; and every form of Double Consciousness, from simple sleep-walking to an alternation of two very similar states of mental existence, presented itself during one long period of the disorder.—It is worth noting that in this case the exciting cause of the disorder lay in the disappointment of affections long cherished in secret; but the nutrition of the nervous system had been previously impaired by anxiety and excessive mental exertion. The first access of the disorder was kept off by the influence of a very determined will; but when the malady had fully developed itself, it resisted every kind of treatment for four years. The catamenial discharge remained very scanty during the whole of that time, and was sometimes absent altogether; and the recurrence of the period was almost invariably marked by an aggravation of the spasmodic attacks, and frequently by pains resembling those of the first stage of labour. A slow and almost imperceptible improvement was taking place, when circumstances occurred, which gave a new turn to the feelings; a fresh attachment was formed, which was happily reciprocated; and from that time the cure rapidly advanced, the convulsive and paraplegic affections being speedily recovered-from, and nothing being left but dysmenorrhœa, which still continued to be occasionally accompanied by severe cramps, and sometimes by general convulsion, coma, &c. This was not altogether corrected, though improved, by marriage; and any emotional excitement of an unpleasant kind was sure to produce an additional aggravation. The state of the os uteri was then examined; and as it was found to be unduly contracted, cautious dilatation by sponge-tents was practised. This had the best results; the dysmenorrhœa soon abated; pregnancy supervened, and after a miscarriage (which seemed traceable to emotional excitement, coinciding with the monthly nisus) a second pregnancy, which went on to the full term; and no return of the spasmodic attacks has since occurred.—It is worthy of note that in this case there was an hereditary predisposition to Gout, which seemed once to manifest itself in a peculiar affection of the tissues about the wrist-joint, of a character rather gouty than rheumatic.

† See Dr. Laycock "On the Nervous Diseases of Women," pp. 161 et seq.

correct to affirm, that disorder of the nutritive or secretory functions of the sexual system is essential to the production of the hysteric condition. The influence of Emotional states upon this condition, is among the most remarkable features in the history of the disorder. There can be little doubt that habitual indulgence of the feelings, especially when these are of a painful kind, has a direct tendency to affect the nutrition of the nervous system; but when these feelings have special reference to sexual subjects, they will exert a powerful indirect influence, by fixing the mind on the genital system, and thereby modifying its condition (CHAP. XVIII.). In either of these modes, the habitual emotional state acts as a 'predisposing cause;' but we constantly observe that, when the hysteric diathesis is established, any particular access of emotional excitement, even though it be of a pleasurable nature, induces the hysteric paroxysm; and it is by making a powerful effort to restrain the feelings, that the Will, if the patient can be led to exert it, has so much control over the hysterical tendency. It is generally, however, a part of the complaint, that the Will *cannot* be effectually exerted; and this either on account of the vehemence of the Emotional disturbance, or through an absolute impairment of voluntary power; the state of mind then approximating closely to some forms of Insanity. It is in such circumstances that the influence of powerful motives, adapted to work upon the Will through the feelings, may be brought to bear most effectually in checking the paroxysm; thus it is well known that when the sight of an 'hysteric fit' in one individual tends to induce it in another, a determined threat of severe treatment is the most certain means of keeping it off.—Hence the treatment of Hysteria may be considered as requiring three classes of remedial means;—those, namely, which operate by improving the general state of nutrition of the Nervous System and by diminishing its excitability, these for the most part acting through the blood, and being directed to the increase of its nutritive components and to the elimination of any morbid matter which it may be suspected to contain; those which operate by removing the exciting causes of the paroxysm, among which may be specially reckoned all such as promote the healthful performance of the menstrual function; and lastly, all those which act beneficially on the Mind, diverting or repressing painful emotions, or substituting pleasurable feelings in their place, and strengthening the general control of the Will.

XVII. The foregoing are the chief Convulsive diseases in which the Spinal centres generally are involved; but there are many spasmodic affections of a more limited character, which are traceable to a morbid affection of some particular division of the Spinal Axis. Thus in the various forms of *Spasmodic Asthma*, the Medulla Oblongata would seem to be alone involved; the attacks of this disorder usually resulting from some internal irritation, either in the air-passages themselves, or in the digestive system, producing a reflex contraction of the muscular fibres of the bronchial tubes. In the purely spasmodic stage of *Hooping-Cough*, again, which frequently persists long after all inflammatory symptoms have subsided, we have another example of spasmodic action limited to the respiratory centres; and here we have distinct evidence that the morbid condition originates in the introduction of a poison into the blood. The same may be said of the *Croup-like Convulsion* or *Crowing Inspiration* of Infants, which is an obstruction to the passage of air through the

Glottis, produced by a spasmodic contraction of the constrictors of the larynx; for although the spasmodic action may be immediately brought-on by various kinds of local irritation, such as that occasioned by teething, by the presence of undigested food, or by intestinal disorder, yet there is no doubt that the excitable condition of the Nervous Centres, without which these influences would be inoperative, is dependent upon a defect of nutrition arising from unwholesome food, bad air, or some other cause affecting the system generally.*— Spasmodic closure of the Larynx may occur from other causes. When the *rima glottidis* is narrowed, by effusion of fluid into the substance of its walls, it is very liable to be completely closed by spasmodic action, to which the unduly irritable condition of the mucous membrane will furnish many sources of excitement. Choking, again, does not result so much from the pressure of the food on the air-passages themselves, as from the spasmodic action of the larynx excited by this; and the dislodgement of the morsel by an act of vomiting, is the most effectual means of obtaining relief. — *Tenesmus* and *Strangury* are well-known forms of spasmodic muscular contraction, excited by local irritation acting through the Spinal centres. The abnormal action which leads to Abortion (CHAP. XIX.) is frequently excited in the same manner. —There is a form of *Incontinence of Urine*, which is very analogous to the morbid action just described; the sphincter has its due power; but the stimulus to the evacuation of the bladder is excessive in strength and degree, owing to the acridity of the urine or other causes. The part of the bladder upon which this appears chiefly to act, is the trigonum (which is well known to be more sensitive to the irritation of calculi, than the rest of the internal surface); and Sir C. Bell advises young persons who suffer during the night from this very disagreeable complaint, to lie upon the belly instead of the back, so that the contact of the urine with the trigonum may be delayed as long as possible.

XVIII. As Convulsive diseases are dependent upon excessive activity of the Spinal centres, so do various forms of *Paralysis* arise from disease of the Cord, affecting its proper ganglionic substance, or the connections of its nerve-roots with the Encephalon. If the latter only be impaired, we have an interruption of sensibility and voluntary motion, the reflex actions of the Spinal ganglia being still manifested; but if the former be involved, these reflex actions are suspended no less completely than are the sensori-volitional. There are many peculiar phenomena of Paralysis depending on Spinal lesion, however, which have not yet been explained on any physiological basis. Among these is the fact, to which Dr. Gull has prominently directed attention,† that in Paraplegia dependent upon lesion of the Cord, there is usually greater loss of motion than of sensation; whilst in Paraplegia dependent upon Encephalic disorder, or upon toxic agencies rather affecting the peripheral than the central portions of the nervous system (as seems to be generally the case, for example, in poisoning by lead), affections of the sensibility, sometimes beginning with

* The influence of "change of air" is often as marked in this disease, as it is in the chronic stage of hooping-cough. That an impure atmosphere is of itself sufficient to induce fatal convulsive disorders in infants, has been sufficiently proved on a former occasion (§ 583).

† 'Gulstonian Lectures on the Nervous System,' in "Medical Times," 1849, No. 495.

hyperæsthesia and then proceeding to more or less complete anæsthesia, usually constitute the prominent symptoms.

XIX. Our present knowledge of the Physiology and Pathology of the *Cerebellum* seems to justify the inference, that its special function consists in the coordination of voluntary movements; and the effects of lesions whose influence is limited to this organ, display themselves most constantly in the impairment of this power. — But there are pathological phenomena which seem to indicate, that a centre of sexual sensation has its place in or near the central lobe of the Cerebellum, and that, according to the degree of excitement or of depression of its functional activity, will be the strength or weakness of the sexual desire prompted by the sensation.

XX. Of the morbid affections of the *Sympathetic System,* it is impossible to state anything with precision, in our present state of almost complete ignorance of its physiological actions. It may be stated, however, as an indubitable fact, that, in virtue of the afferent Cerebro-spinal fibres which it contains, it may receive impressions from morbid states of the organs which it supplies, and may transmit these to the Spinal Cord; through which, general convulsive movements, or irregular actions of the Sensorial or even of the Cerebral centres, may be excited. Of this we have an example in the erratic phenomena of Hysteria already referred-to.

[In the foregoing view of the Functions of the Nervous System, the Author has endeavoured to exhibit this most difficult and in many parts obscure subject, under the aspect in which it now presents itself to his own mind; believing that he could thus best explain it to his readers. As his views have been arrived-at by his own careful study of the subject, he has not thought it necessary to be continually referring to other Physiologists, with whose doctrines his own may have more or less of coincidence. He would here state, once for all, that of the older writers on this branch of Physiology, he regards Unzer and Prochaska (whose treatises have been lately re-published by the Sydenham Society) as having displayed the deepest insight into the truth; their doctrines requiring little more than the correction and extension which subsequent anatomical discoveries have afforded, to form part of the present fabric of the science. And he considers it as no unimportant confirmation of his own views, that although arrived-at in complete ignorance of what Unzer had long previously put forth, they have proved to be in harmony, on all essential points, with those of so philosophic and penetrating a thinker.—Of modern Neurologists, the foremost rank is justly to be assigned to Sir C. Bell, for his discovery of the anatomical distinctness of the sensory and motor nerves, and for the inferences to which this discovery led. And the Author is quite of opinion that the re-discovery of the Reflex Function of the Spinal Cord by Dr. M. Hall (which he believes to have been entirely original on that gentleman's part) has constituted an era of no less importance; although his limitation of the doctrine of reflex action to the Spinal ganglia, has subsequently tended, in the Author's opinion, rather to retard than to promote the progress of Neurology. In extending this view to the Sensory Ganglia, and in showing that they minister to a class of 'reflex' actions peculiarly their own, the Author believes that he may claim to have made the first definite attempt to free it from this limitation; and for its further extension to the Cerebrum, Science is indebted to Dr. Laycock, to whose Essay on the Reflex Action of the Brain, the Author has already expressed his obligations. To these he would add the names of Dr. Holland and Dr. Todd, as those of writers from whom he has derived many valuable suggestions, which have not, he trusts, been without fruit in his own mind.—It is a circumstance not devoid of interest, that, during the present century, notwithstanding the large amount of anatomical and experimental inquiry which has been directed to the Nervous System both in France and Germany, and the vast addition to our knowledge of *details* which has hence arisen, the great advances in the *general doctrines* of this department of the science should have been made by British Physiologists.]

# CHAPTER XV.

## OF SENSATIONS, AND THE ORGANS OF THE SENSES.

### 1.—*Of Sensation in General.*

850. By the term *Sensation* is rightly understood that change in the condition of the Mind, by which we become aware of an *impression* made upon some part of the Body; or, in a briefer form of expression, it may be defined to be the *consciousness of an impression.* Some physiologists have, it is true, spoken of a *sensation without consciousness;* but it seems very desirable to limit the term to the mental change; since the word *impression* serves to designate the change produced in the afferent nerves by an external cause, up to the point at which the mind becomes conscious of it. We have seen reason to believe, that the impressions communicated to the Spinal Cord may there excite motor actions, without occasioning true Sensation; and it would seem to be with a certain part of the Encephalon only, that the Mind possesses the relation necessary for the production of such a change in it. Hence this organ is spoken of as the *Sensorium.* For the reasons already given (§§ 732–4), it seems probable that the ganglia of Special Sensation are the essential instruments of this function, rather than the Cerebral Hemispheres. The afferent nervous fibres, which connect the various parts of the body with the Sensorium, are termed *sensory;* and these are distributed in very different proportions to different parts. Those parts of the body which are endowed with sensory fibres, and impressions on which, therefore, give rise to sensation, are ordinarily spoken of as *sensible;* and different parts are spoken of as sensible in different degrees, according to the strength of the sensation which is produced by a corresponding impression on each. In accordance with what was formerly stated (§ 355) of the dependence of all Nervous action on the continuance of the Circulation of the blood, it is found that the sensory nerves are distributed pretty much in the same proportion as the blood-vessels; that is to say, in the non-vascular tissues, —such as the epidermis, hair, nails, cartilage, and bony substance of the teeth,—no nerves exist, and there is an entire absence of sensibility; and in those whose vascularity is trifling, the sensibility is dull, as is the case with bones, tendons, ligaments, fibrous membranes, and other parts whose functions are simply mechanical, and even with serous and areolar membranes. Many of these textures are acutely sensible, however, under certain circumstances; thus, although tendons and ligaments may be wounded, burned, &c., without giving rise to much consciousness of the injury, they cannot be stretched without the production of considerable pain; and the fibrous, serous, and areolar tissues, when their vascularity is increased by inflammation, also become extremely susceptible of painful impressions. All very vascular parts, however, do not possess acute sensibility; the muscles, for instance, are furnished with a large supply of blood, to enable them to perform their peculiar function; but they are

not sensible in by any means the same proportion. Even the substance of the brain, and of the nerves of special sensation, appears to be destitute of this endowment; and the same may be said of the mucous membranes lining the interior of the several viscera, which, in the ordinary condition, are much less sensible than the membranes that cover those viscera, although so plentifully supplied with blood for their especial purposes. The most sensible of all parts of the body, is the Skin, in which the sensory nerves spread themselves out into a minute network; and even of this tissue, the sensibility differs greatly in different parts. The organs of *special* sensation become, by the peculiar character of the nerves with which they are supplied, the recipients of impressions of a particular kind: thus, the eye is sensible to light, the ear to sound, &c.; and whatever amount of *ordinary* sensibility they possess, is dependent upon other sensory nerves. The eye, for example, contrary to the usual notions, is a very insensible part of the body, unless affected with inflammation; for though the mucous membrane which covers its surface, and which is prolonged from the skin, is acutely sensible to tactile impressions, the interior is by no means so, as is well known to those who have operated much on this organ. And there are many parts of the body that are supplied with the common sensory nerves, which receive and convey to the mind impressions of particular kinds, with much greater readiness than they communicate those of a different description.

851. An active Capillary Circulation being essential to the Sensibility of every part supplied with nerves, any cause which retards this deadens the sensibility, as is well seen with regard to Cold; and, on the other hand, an increase in its energy produces a corresponding increase in the sensibility, as is peculiarly evident in the 'active congestion' which usually precedes and accompanies Inflammation. A diminution or increase of sensibility to external impressions may arise, however, not only from an abnormal state of the circulation in the organ or part itself, but from the similar conditions affecting that part of the sensorium, in which the impressions are received. Thus in those various conditions of the Encephalon, in which either a stagnation of the circulation, or an abnormal state of the blood, occasions a diminished functional activity in the Sensorial centres, this is marked by obtuseness to sensory impressions; on the other hand, in active congestion of the brain, the most ordinary external impressions produce sensations of an unbearable violence; and there are some peculiar conditions of the nervous system, known under the name of hysterical, in which the patients manifest the same discomfort, even when the circulation is in a feeble, rather than in an excited state.* It is remarkable that the sensibility of the mucous membranes lining the internal organs, is less exalted by the state of inflammation, than is that of most other parts; and in this arrangement we may trace a wise and beneficent provision; since, were it otherwise, the functions necessary to life could not be performed without extreme distress, with a very moderate amount of disorder in the viscera. If a joint is inflamed, we can give it rest; but to the actions of the alimentary canal we can give little voluntary respite.

* The influence of toxic agents introduced into the blood, in producing Anæsthesia and Hyperæsthesia, constitutes a very wide field of inquiry, which is well deserving of careful cultivation. It is remarkable that *Lead* should be capable of inducing either of these states.

852. The feelings of Pain or Pleasure which are connected with particular sensations, cannot (for the most part at least) be explained upon any other principle, than that of the necessary association of these feelings, by an original law of our nature, with the sensations in question. As a general rule, it may be stated, that the *violent* excitement of *any* sensation is disagreeable, even when the same sensation in a moderate degree may be a source of extreme pleasure. This is the case alike with those impressions, which are communicated through the organs of sight, hearing, smell, and taste, as with those that are received through the nerves of common sensation; and there can be no doubt that the final cause, or purpose, of the association of painful feelings with such violent excitement, is to stimulate the individual to remove himself from what would be injurious in its effects upon the system. Thus, the pain resulting from violent pressure on the cutaneous surface, or from the proximity of a heated body, gives warning of the danger of injury, and excites mental operations destined to remove the part from the influence of the injurious cause: and this is shown by the fact, that loss of sensibility is frequently the indirect occasion of severe lesions,—the individual not receiving the customary intimation that an injurious process is taking place.* Instances have occurred, in which severe inflammation of the membrane lining the passages has resulted from the effects of ammoniacal vapours, introduced into them during a state of syncope,—the patient not receiving that notice of the irritation, which, in an active condition of his nervous system, would have prevented him from inhaling the noxious agent.

853. It is a general rule, with regard to all sensations, that their intensity is much affected by *Habit;* being greatly diminished by frequent and continual repetition. This is not the case, however, with regard to those sensations, to which the *attention* is peculiarly directed; for these lose none of their acuteness by frequent repetition; on the contrary, they become much more readily cognizable by the mind. We have a good example of both facts, in the effects of sounds upon sleeping persons (§ 843). The general law, then, seems to be, that Sensations, *not attended-to,* are blunted by frequent repetition; and this may perhaps be connected with certain other general facts, which lie under the observation of every one.—It is well known that the vividness of sensations

* The following case, recorded in the "Journal of a Naturalist," affords a remarkable instance of this general fact. The correctness of the statement having been called in question, it was fully confirmed by Mr. Richard Smith, the late senior surgeon of the Bristol Infirmary, under whose care the sufferer had been. "A travelling man, one winter's evening, laid himself down upon the platform of a lime-kiln, placing his feet, probably numbed with cold, upon the heap of stones, newly put on to burn through the night. Sleep overcame him in this situation; the fire gradually rising and increasing, until it ignited the stones upon which his feet were placed. Lulled by the warmth, the man slept on; the fire increased until it burned one foot (which probably was extended over a vent-hole) and part of the leg above the ankle entirely off, consuming that part so effectually, that a cinder-like fragment was alone remaining,—and still the wretch slept on! and in this state was found by the kilnman in the morning. Insensible to any pain, and ignorant of his misfortune, he attempted to rise and pursue his journey, but missing his shoe, requested to have it found; and when he was raised, putting his burnt limb to the ground to support his body, the extremity of his leg-bone, the tibia, crumbled into fragments, having been calcined into lime. Still he expressed no sense of pain, and probably experienced none; from the gradual operation of the fire, and his own torpidity during the hours his foot was consuming. This poor drover survived his misfortunes in the hospital about a fortnight; but the fire having extended to other parts of his body, recovery was hopeless."—See also § 349, note.

depends rather on the degree of *change* which they produce in the system, than on the *absolute amount* of the impressing force; and this is alike the case with regard to the special and the ordinary sensations. Thus, our sensations of heat and cold are entirely governed by the previous condition of the parts affected; as is shown by the well-known experiment of putting one hand into hot water, the other into cold, and then transferring both to tepid water, which will seem cool to one hand, and warm to the other. Every one knows, too, how much more we are affected by a warm day at the commencement of summer, than by an equally hot day later in the season. The same is the case in regard to light and sound, smell and taste. A person going out of a totally dark room into one moderately bright, is for the time painfully impressed by the light, but soon becomes habituated to it; whilst another, who enters it from a room brilliantly illuminated, will consider it dark and gloomy. Those who are constantly exposed to very loud noises, become almost unconscious of them, and are even undisturbed by them in illness; and the medical student well knows, that even the effluvia of the dissecting-room are not perceived, when the organ of smell is habituated to them; although an intermission of sufficient length would, in either instance, occasion a renewal of the first unpleasant feelings, when the individual is again subjected to the impression.—Again, it is a well-known fact, that impressions made upon the organs of sense continue to affect the consciousness for a time, after the cause of the impression has ceased: it is in this manner that a musical tone which seems perfectly continuous, results from a series of consecutive vibrations, following each other with a certain rapidity; and that a line or circle of light is produced by a luminous body moving with a certain velocity. And there seems reason to believe that sensorial changes of frequent recurrence produce a modification in the nutrition of the Sensorium itself, which *grows-to* them, as it were, just as the Cerebrum may be considered as growing-to the mode in which it is habitually exercised (§ 807); for not only would the production of such a modification be quite in accordance with the general phenomena of Nutrition,* but we can scarcely otherwise explain the progressive formation of that connection between sensorial changes and motor actions, which gives rise to the 'secondarily automatic' movements (§ 749).—Hence it seems reasonable to attribute that diminution in the force of Sensations which is the consequence of their habitual recurrence, to the want of such a *change* in the condition of the Sensorium as is needful to produce an impression on the consciousness; the effects which they at first induced being no longer experienced in the same degree, when the structure of the part has accommodated itself to them.

854. It is curious, also, that the feelings of Pain or Pleasure, which unaccustomed sensations excite, are often exchanged for each other, when the system is habituated to them; this is especially the case, in regard to impressions communicated through the organs of Smell and

* We have a remarkable exemplification of this, in the *tolerance* which may be gradually established in the system for various toxic agents, especially for such as particularly affect the Nervous substance, such as Opium or Alcohol. It seems impossible to explain this tolerance on any other hypothesis, than that of the alteration of the nutrition of the tissue by repeated doses, so that no further change can be produced by the quantity originally taken.

Taste. There are many articles in common use among mankind,—such as tobacco, fermented liquors, &c., the use of which cannot be said to produce a natural enjoyment, since they are at first unpleasant to most persons; and yet they first become tolerable, then agreeable; and at last the want of them is felt as a painful privation, and the stimulus must be applied in an increasing degree, in order to produce the usual effect.

855. It is through the medium of Sensation, that we acquire a knowledge of the material world around us, by the psychical operations which its changes excite in ourselves. The various kinds or modes of Sensation excite in us various ideas regarding the properties of matter; and these properties are known to us, only through the changes which they produce in the several organs (§ 786). It is well known that instances exist, in which, from some imperfection of the organization, there is an incapacity for distinguishing colours or musical tones, whilst there is no want of sensibility to light or sound; and that some persons are naturally endowed with a much greater range of the sensory faculties, than others possess. Hence it does not seem at all improbable, that there are properties of matter, of which none of *our* senses can take immediate cognizance; and which other beings might be formed to perceive, in the same manner as *we* are sensible to light, sound, &c. Thus many animals are affected by atmospheric changes, in such a manner, that their actions are regarded by Man as indications of the probable state of the weather; and the same is the case in a less degree with some of our own species, who are peculiarly susceptible of the same influences.—Now the most universal of all the qualities or properties of Matter, on which, in fact, our notion of it is chiefly founded (§ 804), is its occupation of space, producing a more or less complete *resistance* to displacement; and this quality is that through which alone any knowledge of the external world can be obtained by a large proportion of the lower Animals; *contact* between their own surface and some material body, being required to produce sensation. We shall presently see, however, that the idea of the *shape* of a body which we form from the touch, results from a very complex process, such as animals of the lower grades can scarcely be supposed to exercise. There can be little doubt that, next to the mere sense of resistance, sensibility to *temperature* is the most universally diffused through the Animal kingdom; and probably the consciousness of *luminosity* is the next in the extent of its diffusion.* It is probable that the sense of *taste* (which has a close affinity to that of touch) exists very low down in the animal scale, being obviously of great importance in the selection of food; but the Anatomist has no means of ascertaining where this refinement exists, and where it does not; since the organs of taste and touch are very similar. The sense of *hearing* does not seem to be distinctly present among the Invertebrate animals, except in such as approach most nearly to the Vertebrata; it is not improbable, however,

* There is good reason to believe, from observation of their habits, that many animals are susceptible of the influence, and are directed by the guidance, of light; whilst their organs are not adapted to receive true visual impressions, or to form optical images: and such would seem to be the function of the red spots, frequently seen on prominent parts of the lower Articulata and Mollusca, and even of some Radiata. Wherever these are of sufficient size to allow their structure to be examined, they are found to be largely supplied with nerves, but to be destitute of the peculiar organization which alone constitutes a true *eye*.

that sonorous vibrations may produce an effect upon the system of those animals, which do not receive them as *sound*. The sense of *smell*, which is concerned with one of the least general properties of matter, appears to be the least widely diffused among the whole; being only possessed in any high degree by Vertebrated animals, and being but feebly present in a large proportion of these.

856. Besides the various kinds of sensibility which have been just enumerated, there are others which are ordinarily associated together, along with the sense of material resistance (and its several modifications), and the sense of temperature, under the head of Common Sensation; but several of them, especially those which originate in the body itself, can scarcely be regarded in this light. Such are the feelings of hunger and thirst; that of nausea; that of distress resulting from suspended aeration of the blood; that of "sinking at the stomach," as it is vulgarly but expressively described, which results from strong mental emotion; the sexual sense, and perhaps some others.—Now in regard to all these, it is impossible in the present state of our knowledge to say, whether their peculiarity results from the particular constitution of the nerves that receive and convey them, or only from a modification in the impressing causes, from the particular endowments of their ganglionic centres, and from the mode in which they operate. Thus we have no evidence whether the nervous fibrils, which convey from the lungs the sense of distress resulting from deficient aeration, are of the same or of a different character from those which convey from the surface of the air-passages the sense of the contact of a foreign body. But as we know that all the trunks, along which these peculiar impressions travel, do minister to ordinary sensation, whilst the nerves of truly special sensation are not sensible to common impressions, it is evident that the probability seems in favour of the identity of the fibres, which minister to these sensations, with those of the usual sensory character. We shall see that, with regard to the sense of Temperature, there is strong evidence that its peculiarity depends on the speciality of the apparatus by which impressions are received at the peripheral extremities of the tactile nerves, rather than upon any peculiarity in the transmitting fibres (§ 866).

857. There are certain external causes which can excite changes in the Sensorium through several different channels; the sensation being in each case characteristic of the particular nerve on which the impression is made. Thus pressure, which produces through the nerves of common sensation the feeling of resistance, is well known to occasion, when exerted on the eye, the sensation of light and colours; and, when made with some violence on the ear, to produce tinnitus aurium. It is not so easy to excite sensations of taste and smell, by mechanical irritation; and yet, as Dr. Baly * has shown, this may readily be accomplished in regard to the former. The sense of nausea may be easily produced, as is familiarly known, by mechanical irritation of the fauces. Electricity still more completely possesses the power of affecting all the sensory nerves with the changes which are peculiar to them; for, by proper management, an individual may be made conscious at the same time of flashes of light, of distinct sounds, of a phosphoric odour, of a peculiar taste, and of pricking

* Translation of Müller's "Elements of Physiology," p. 1062, *note*.

sensations, all excited by the same cause, the effects of which are modified by the respective peculiarities of the instruments through which it operates. — But although there are some stimuli which can produce sensory impressions on all the nerves of sensation, it will be found that those to which any one organ is *peculiarly* fitted to respond, produce little or no effect upon the rest. Thus the ear cannot distinguish the slightest difference between a luminous and a dark object. A tuning-fork, which, when laid upon the ear whilst vibrating, produces a distinct musical tone, excites no other sensation, when placed upon the eye, than a slight jarring feeling. The most delicate touch cannot distinguish a substance which is sweet to the taste, from one which is bitter; nor can the taste (if the communication between the mouth and the nose be cut off) perceive anything peculiar in the most strongly-odoriferous bodies.—It may hence be inferred that no nerve of *special* sensation can, by any possibility, take-on the function of another.

858. But whilst there is evidence of the peculiar aptitudes of the different Sensory nerves, to receive and convey impressions of particular kinds, yet there can be no doubt that their special endowments are in great degree dependent upon those of the *central* organs in which they terminate. For with regard to all kinds of Sensation it is to be remembered, that the change of which the Mind is informed, is *not* the change at the peripheral extremities of the nerves, but the change communicated to the Sensorium; hence it results, that external agencies can give rise to no kind of sensation, which cannot also be produced by internal causes, exciting changes in the condition of the nerves in their course. This very frequently happens in regard to the senses of sight and hearing; flashes of light being seen, and ringing sounds in the ears being heard, when no external stimulus has produced such impressions. The production of odorous and gustative sensations from internal causes, is perhaps less common; but the sense of nausea is more frequently excited in this manner, than by the direct contact of the nauseating substance with the tongue or fauces. The various phases of common sensibility often originate thus; and the sense of temperature is frequently affected without any corresponding affection of the tactile sensations, a person being sensible of heat or of chilliness in some part of his body, without any real alteration of its temperature. The most common of the internal causes of these *subjective* sensations (as they have been termed, in contradistinction to the *objective*, which result from a real material object), is congestion or inflammation; and it is interesting to remark that this cause, operating through each nerve, produces in the sensorium the changes to which that nerve is usually subservient. Thus, congestion in the nerves of common sensation gives rise to feelings of pain or uneasiness; but when occurring in the retina and optic nerve it produces flashes of light; and in the auditory nerve it occasions 'a noise in the ears.'—But further, the phenomena of *subjective* sensation often originate in peculiar conditions of the Encephalon itself, and not in the organs of sense or the nervous trunks; thus, in dreaming, we have frequently very vivid pictures of external objects presented to our minds; and we sometimes distinctly hear voices and musical tones, or have perceptions (though this is less common) of tastes and odours. The phenomena of spectral illusions are very nearly connected with those of dreaming; both may be in some

degree influenced by external causes, acting upon the organs of sensation, which are misinterpreted (as it were) by the mind, owing to its state of imperfect operation; but both also may entirely originate in the central organs. There seems to be no difference, in the feelings of the individual, between the sensations thus originating, and those which are produced in the usual manner; for we find that, unless otherwise convinced by their own reason, persons who witness spectral illusions believe as firmly in the reality of the objects that come before their minds, as if the images of those objects were actually formed on their retinæ. This is another proof, if any were wanting, that the organ of sense, and the nerve belonging to it, are but the instruments by which certain changes are produced in the Sensorium; by which changes, and not by the immediate impressions of the objects, our Consciousness is really affected.—There is yet another mode, however, in which subjective sensations may be excited; namely, by sensations originating in objective impressions on *other* parts. Thus the irritation of a calculus in the bladder gives rise to pain at the end of the penis; disease of the hip-joint is often first indicated by pain in the knee; irritation of the ovary will cause pain under the mamma; various disorders of the liver occasion pain under the left scapula; attention is often drawn to diseases of the heart by shooting pains along the arms; stimulation of the nipple, whether in the male or female, gives rise to peculiar sensations referred to the genital organs; the sudden introduction of ice into the stomach will cause intense pain in the supra-orbital region, and the same pain is frequently occasioned by the presence of acid in the stomach, and may be very quickly relieved by its neutralization with an alkali. It will be seen that in most of these cases it is impossible to refer the sensations to any direct nervous connection with the parts on which the impressions are made; and they can scarcely be otherwise accounted-for, than by supposing that these impressions produce sensorial changes, which are referred to other parts, in virtue of some central track of communication with them, analogous to that through which reflex movements are excited. There are circumstances, indeed, which seem to render it not improbable, that just as the impression brought by the afferent nerves to the central organs, excites a reflex movement by disturbing the polarity of a motor nerve, it may excite a 'reflex sensation' by disturbing the polarity of a sensory nerve. Certain it is that, after the long continuance of some of these reflex sensations, the organs to which they are referred themselves become diseased, although previously quite healthy; thus, pain in the testicle is frequently induced by irritation having its seat in the lower part of the spine, but, if this continue, some morbid affection of the testicle itself is likely to supervene; and Sir B. Brodie * has recorded several cases, in which 'nervous' pains in various parts, apparently of a purely subjective character, have been followed by pain and swelling of the integuments. These phenomena are perhaps due to that habitual direction of the consciousness to the part, which is prompted by the habitual sensation; this condition, as we shall see hereafter (CHAP. XVIII.), being itself adequate to the production of changes in its ordinary nutritive action.

859. It seems to be by an innate law of our constitution, that these

* "On Local Nervous Affections," 1837.

subjective sensations, whether originating at the central terminations of nerves, or in the course of their trunks, should be referred by the mind to the ordinary situations of their peripheral terminations; even though these should not exist, or should be destitute of the power of receiving impressions. Thus after amputations, the patients are for some time affected with sensations (originating probably in the cut extremities of the nerves), which they refer to the removed extremities; the same has been noticed in regard to the eye, as well when it has been completely extirpated, as when its powers have been destroyed by disease. The effects of the Taliacotian operation also exhibit the operation of this law in a curious manner; for until the flap of skin from which the new nose is formed, obtains vascular and nervous connections in its new situation, the sensation produced by touching it is referred to the forehead. Another interesting illustration of it may be obtained by the following very simple experiment: — if the middle finger of either hand be crossed behind the fore-finger, so that its extremity is on the radial side of the latter, and the ends of the two fingers thus disposed be rolled over a marble, pea, or other round body, a sensation will be produced, which, if uncorrected by reason, would cause the mind to believe in the existence of two distinct bodies; this is due to the impression being made at the same time upon the radial side of the fore-finger, and the ulnar side of the middle finger, — two joints which, in the natural position, are at a considerable distance.

860. Sensations of a purely subjective nature may excite precisely the same muscular movements, or other changes in the bodily system, as do similar sensations produced by objective realities. Of this we have abundant evidence in the effects of sensations called-up by ideas (§§ 758, 863); the following example, however, is peculiarly valuable, as showing that the sensation still operates in directing movement, even though there be an intellectual consciousness that there is no objective cause for it, and that the movement is consequently inappropriate. A lady nearly connected with the Author, having been frightened in childhood by a black cat, which sprang up from beneath her pillow just as she was laying her head upon it, was accustomed for many years afterwards, whenever she was at all indisposed, to see a black cat on the ground before her; and although perfectly aware of the spectral character of the appearance, yet she could never avoid lifting her foot as if to step over the cat, when it seemed to be lying in her path.

861. The acuteness with which particular Sensations are felt, is influenced in a remarkable degree by the *attention* they receive from the mind. If the mind be entirely inactive, as in profound sleep, no sensation whatever is produced by ordinary impressions; and the same is the case when the attention is so completely concentrated upon some object of thought or contemplation, that sensations altogether unconnected with it fail to make any impression on the perceptive consciousness. On the other hand, when the attention is from any cause strongly directed upon them, impressions very feeble in themselves produce sensations of even painful acuteness; thus every one knows how much a slight itching of some part of the surface may be magnified by the direction of the thoughts to it, whilst, as soon as they are forced by some stronger impression into another channel, the irritation is no longer felt; so, too, it must be

within the experience of most persons, how vividly sounds are perceived when they break-in upon the stillness of the night, being increased in strength, not only by the contrast, but by absorbing the whole attention. An interesting experiment is mentioned by Müller, which shows how completely the mind may be unconscious of impressions communicated to it by one organ of sense, when occupied, even without a distinct effort of the will, by those received through another. If we look at a sheet of white paper through two differently-coloured glasses at the same time,—one being placed before each eye,—the resulting sensation is seldom that of a mixture of the colours: if the experiment be tried with blue and yellow glasses, for example, we do not see the paper of an uniform green; but the blue is predominant at one moment, and the yellow at another; or blue nebulous spots may present themselves on a yellow field, or yellow spots on a blue field. We perceive from this experiment, that the attention may not only be directed to the impressions made on either retina, to the complete exclusion of those of the other, but it may be directed to those made on particular spots of either. This may be noticed, again, in the process by which we make ourselves acquainted with a landscape or a picture; if our attention be directed to the whole field of vision at once, we see nothing distinctly; and it is only by abstracting ourselves from the contemplation of the greater part of it, and by directing our attention to smaller portions in succession, that we can obtain a definite conception of the details. The same is the case in regard to auditory impressions; and here the power of attention, in causing one sensation or series of sensations to predominate over others which are really more intense, is often most remarkably manifested. When we are listening to a piece of music played by a large orchestra, for example, we may either attend to the combined effect of all the instruments, or we may single-out any one part in the harmony, and follow this through all its mazes; and a person with a practised ear (as it is commonly but erroneously termed, it being not the ear, but the mind, that is practised,) can even distinguish the sound of the weakest instrument in the whole band, and can follow its strain through the whole performance. This attention to a single element can only be given, however, by withdrawing the mind from the perception of the remainder; and a musician who thus listens, will have very little idea of the rest of the harmonic parts, or of the general effect. In fact, when the mind is thus directed, by a strong effort of the will, into a particular channel, it may be almost considered as unconscious *quoad* any other impressions.

862. The effects of attention are not only manifested in regard to the sensations which are excited by external impressions, but also in respect to those which originate within the system. Every one is aware how difficult it is to keep the body perfectly quiescent,* especially when there is a particular motive for doing so, and when the attention is strongly directed to the object. This is experienced even whilst a photogenic likeness is being taken, when the position is chosen by the individual, and a support is adapted to assist him in retaining it; and it is still more strongly felt by the performers in the 'tableaux vivans,' who cannot keep up the effort for more than three or four minutes. Now it is well known

* Of course the movements of respiration and winking are left out of the question.

hat, when the attention is strongly directed to an entirely different object when we are listening, for example, to an eloquent sermon, or an intersting lecture), the body may remain perfectly motionless for a much onger period; the uneasy sensations, which would otherwise have inluced the individual to change his position, not being perceived: but no ,ooner is the discourse ended, than a simultaneous movement of the vhole audience takes place, every one then becoming conscious of some liscomfort, which he seeks to relieve. This is the case also in regard to :he respiratory sensation; for it may generally be observed that the usual ·eflex movements do not suffice for the perfect aeration of the blood, ınd that a more prolonged inspiration, prompted by an uneasy feeling, :akes place at intervals; but under such circumstances as those just ılluded-to, this feeling is not experienced until the attention ceases to be :ngaged by a more powerful stimulus, and then it manifests itself by the leep inspirations, which accompany, in almost every individual, the general movement of the body.

863. It is remarkable that not merely are subjective sensations, like all others, rendered more intense by the direction of the attention to them, but they may be actually called into existence by the fixation of the attention on certain parts of the body, still more, by the belief in the existence of objective causes for such sensations. The "effects of mental attention on bodily organs" have been specially pointed out by Dr. Holland;* from whose examples the following may be cited in proof of the foregoing position. "The attention concentrated, for so by an effort of will it may be, on the head or sensorium, gives certain feelings of tension and uneasiness, caused possibly by some change in the circulation of the part; though it may be an effect, however difficult to be conceived, on the nervous system itself. Persistence in this effort, which is seldom indeed possible beyond a short time without confusion, produces results of much more complex nature, and scarcely to be defined by any common terms of language." "Stimulated attention will frequently give a local sense of arterial pulsation where not frequently felt, and create or augment those singing noises in the ears, which probably depend on the circulation through the capillary vessels." A similar direction of consciousness to the region of the stomach, creates in this part a sense of weight, oppression, or other less definite uneasiness; and, when the stomach is full, appears greatly to disturb the due digestion of the food. The state and action of the bowels are much influenced by the same cause." A peculiar sense of weight and restlessness approaching to cramp, is felt in a limb, to which the attention is particularly directed. So, again, if the attention be steadily directed to almost any part of the surface of the body, some feeling of itching, creeping, or tickling will soon be experienced.—The fact that sensations may be *modified* by previous beliefs, which must be within the experience of every one, is remarkably illustrated by the well-known exclamation of Dr. Pearson, "Bless me, how heavy it is," when he first poised upon his finger the globule of potassium produced by the battery of Davy; his preconception of the coincidence between metallic lustre and high specific gravity, causing him to feel *that* as ponderous,

* See his valuable Essay on that subject in his "Medical Notes and Reflections," and in his "Chapters on Mental Physiology."

which the unerring test of the balance determined to be lighter than water.—Of the absolute creation of subjective sensations by the belief in the existence of their objective causes, the two following cases, related by Prof. Bennett,* are very satisfactory examples; the effect of the idea not being limited to the production of the sensations, but extending itself to the consequences which would have followed those sensations if their supposed cause had been real. "A clergyman told me, that some time ago suspicions were entertained in his parish, of a woman who was supposed to have poisoned her newly-born infant. The coffin was exhumed, and the procurator-fiscal, who attended with the medical men to examine the body, declared that he already perceived the odour of decomposition, which made him feel faint, and in consequence he withdrew. But, on opening the coffin, it was found to be empty; and it was afterwards ascertained that no child had been born, and consequently no murder committed." The second case is yet more remarkable. "A butcher was brought into the shop of Mr. Macfarlan, the druggist, from the market-place opposite, labouring under a terrible accident. The man, on trying to hook-up a heavy piece of meat above his head, slipped, and the sharp hook penetrated his arm, so that he himself was suspended. On being examined, he was pale, almost pulseless, and expressed himself as suffering acute agony. The arm could not be moved without causing excessive pain; and in cutting off the sleeve, he frequently cried out; yet when the arm was exposed, it was found to be quite uninjured, the hook having only traversed the sleeve of his coat!" In this and similar cases, the sensation was perfectly *real* to the individual who experienced it; but it originated in a Cerebral (ideational) change which produced its impression through the nerves of *internal* sensation (§ 758), instead of in an impression upon the nerves of the *external* senses to which it was referred. Of this kind of action we have seen other examples, in the production of sensations by 'suggestion' in the state of artificial reverie (§ 825). And the excitement of the peculiar sensation of tickling in a ticklish person by any movement that suggests the idea, and of that of creeping or itching by the mention of bed-infesting insects to those who are peculiarly liable to their attacks, are familiar instances of the same fact; which strongly confirms the general doctrines heretofore advanced, respecting the analogy between the peripheral surface of the Cerebrum and the peripheral expansions of the Sensory nerves, as regards their mutual relations to the Sensorium (§ 753).

### 2. *Sense of Touch.*

864. By the sense of Touch, as commonly understood, is meant that modification of the common sensibility of the body, of which the Cutaneous surface is the especial seat. The Skin is peculiarly adapted for this purpose, not merely by the large amount of sensory nervous fibres which are distributed in its substance, but also by its possession of a papillary apparatus in which these nerves terminate, or rather commence. The *papillæ* are little elevations of the surface of the cutis, easily perceptible by the aid of a lens; each is chiefly composed of a vascular loop (Fig. 138), in close relation with a similar loop formed by the nervous fibril; and

* "The Mesmeric Mania of 1851." Edinburgh, 1851.

also encloses (as appears from the recent researches of Professors Wagner and Kölliker) an 'axile body,' composed of a mass of homogeneous areolar tissue with an external layer of imperfectly-developed elastic tissue, and essentially similar to the bundles of fibrous tissue encircled by elastic fibres which are to be found in the cutis. These 'axile bodies' are only to be found in the papillæ of those parts which are distinguished for acuteness of tactile sensibility; and hence we cannot regard them as *essential* to the exercise of the sense of touch, their function probably being to *intensify* tactile impressions, where delicacy of touch is peculiarly required.* The number of these papillæ within any given area, pretty closely corresponds with the degree of sensibility of that part of the surface; thus we find them most abundant on the hands, especially towards the points of the fingers, and on the lips and tongue. Some interesting observations have been made by Prof. Weber, on the sensibility of different parts of the skin. His mode of ascertaining this, was to touch the surface with the legs of a pair of compasses, the points of which were guarded with pieces of cork; the eyes being closed at the time, the legs were approximated to each other, until they were brought within the smallest distance at which they could be felt to be distinct from one another, which has been termed by Dr. Graves 'the limit of confusion.'—The following are some of the results of his experiments.

FIG. 138.

Capillary net-work at margin of lips.

| | | | |
|---|---|---|---|
| Point of tongue | ½ of a line. | Mucous membrane of gums | 9 lines. |
| Palmar surface of third phalanx | 1 line. | Lower part of forehead | 10 " |
| Red surface of lips | 2 lines. | Lower part of occiput | 12 " |
| Palmar surface of second phalanx | 2 " | Back of hand | 14 " |
| Dorsal surface of third phalanx | 3 " | Neck, under lower jaw | 15 " |
| Palmar surface of metacarpus | 3 " | Vertex | 15 " |
| Tip of the nose | 3 " | Skin over patella | 16 " |
| Dorsum and edge of tongue | 4 " | ——— sacrum | 18 " |
| Part of lips covered by skin | 4 " | ——— acromion | 18 " |
| Palm of hand | 5 " | Dorsum of foot | 18 " |
| Skin of cheek | 5 " | Skin over sternum | 20 " |
| Extremity of great toe | 5 " | Skin beneath occiput | 24 " |
| Hard palate | 6 " | Skin over spine, in back | 30 " |
| Dorsal surface of first phalanx | 7 " | Middle of the arm | 30 " |
| Dorsum of hand | 8 " | ——— thigh | 30 " |

It is curious that the distance between the legs of the compasses seemed to be greater (although really so much less), when it was felt by the more sensitive parts, than when it was estimated by parts of less distinct sensibility. With the extremities of the fingers and the point of the tongue, the distance could be distinguished most easily in the longitudinal direction; on the dorsum of the tongue, the face, neck, and extremities, the distance could be recognised best when the points were placed transversely. As a general fact, it seems that the sensibility of the trunk

* The accounts of the structure of the tactile papillæ given by Prof. Kölliker in his "Mikroskopische Anatomie," band ii. p. 24, and in the "Zeitschrift für Wissenschaften Zoologie," band iv. heft 1, 1852, are here followed. For a notice of the peculiar views of Prof. Wagner, see the "Brit. and For. Med.-Chir. Rev.," vol. x. p. 251.

is greater on the median line, both before and behind, and less at the sides. Differences in the temperature and weight of bodies, were, according to Prof. Weber's observations, most accurately recognized at the parts which were determined to be most sensible by the foregoing method of inquiry.*

865. As already stated (§ 855), the only idea communicated to our minds by the sense of Touch, when exercised in its simplest form, is that of *Resistance;* and it is by the various degrees of resistance which the sensory surface encounters, of which we partly judge by the muscular sense (§ 750), that we estimate the hardness or softness of the body against which we press. It is only when either the sensory surface or the substance touched is made to change its place in regard to the other, that we obtain the additional notion of *extension* or *space;* this also being derived from the combination of the muscular with the tactile sense. By the impressions made upon the papillæ, during the movement of the tactile organ over the body which is being examined, the roughness, smoothness, or other peculiar characters, of the surface of the latter are estimated. Our knowledge of *form,* however, is a very complex process, requiring not merely the exercise of the sense of touch, but also great attention to the muscular sensations.—It is chiefly, as formerly remarked, in the variety of movements of which the hand of Man is capable, that it is superior to that of any other animal; and it cannot be doubted that the sense of Touch thus employed, affords us a very important means of acquiring information in regard to the external world, and especially of correcting many vague and fallacious notions which we should derive from the sense of Sight, if used alone. On the other hand, it must be confessed, that our knowledge would have a very limited range, if this sense were the only medium through which we could acquire ideas. It is probably on the sensations communicated through the Touch, that the idea of the material world, as something external to ourselves, chiefly rests; but this idea is by no means a logical deduction from our experience of these sensations, being rather an instinctive or intuitive perception directly excited by them (§ 790).

866. That the conditions under which certain of the modifications of common sensation operate, are in some respects different from those of ordinary Touch, is very easily shown. Thus, the feeling of tickling is excited most readily in parts which have but a low tactile sensibility, namely, the armpits, flanks, and soles of the feet; whilst in the points of the fingers, whose tactile sensibility is most acute, it cannot be excited. Moreover, the nipple is very moderately endowed with ordinary sensibility; yet by a particular kind of irritation, a very strong feeling may be excited through it.—Again, in regard to Temperature, it is remarked by

* See his Memoir "De Pulsu, Respiratione, Auditu, et Tactu," Lipsiæ, 1834. This method of inquiry has been since pursued by M. H. Belfield-Lefèvre ("Recherches sur la Nature, la Distribution et l'Organ du Sens Tactile," Paris, 1837), and by Prof. Valentin ("Lehrbuch der Physiologie des Menschen," band ii. § 566), with the same general results. It was found by Prof. Valentin, however, that a considerable amount of individual variation exists in regard to the 'limit of confusion;' some persons being able to distinguish the points at one-half or even one-third of the distances required by others.—In the Author's article 'Touch' in the "Cyclopædia of Anatomy and Physiology," vol. iv. p. 1169, will be found a Table including the whole series of observations made by Profrs. Weber and Valentin, the *maxima* and *minima* of the latter being stated, as well as the *means.*

Weber, that the left hand is more sensitive than the right: although the sense of touch is undoubtedly the most acute in the latter. He states that, if the two hands, previously of the same temperature, be plunged into separate basins of warm water, that in which the left hand is immersed will be felt as the warmest, even though its temperature is somewhat lower than that of the other. In regard to the sensations of heat and cold, he points out another curious fact,—that a weaker impression made on a large surface, seems more powerful than a stronger impression made on a small surface; thus, if the forefinger of one hand be immersed in water at 104°, and the whole of the other hand be plunged in water at 102°, the cooler water will be thought the warmer; whence the well-known fact, that water in which a finger can be held, will scald the whole hand. Hence it also follows, that minute differences in temperature, which are imperceptible to a single finger, are appreciated by plunging the whole hand into the water; in this manner, a difference of one-third of a degree may readily be detected, when the same hand is placed successively in two vessels. The judgment is more accurate, when the temperature is not much above or below the usual heat of the body; just as sounds are best discriminated, when neither very acute nor very grave.—Some further experiments have recently been made by Professor Weber, to determine whether the sense of temperature is received through any other channel than the sensory apparatus contained in the integuments.* The first means of which he availed himself for deciding this question, was that afforded by the results of accident or surgical operations, in which a portion of skin had been left deficient. Thus, in three cases in which a large portion of the skin had been destroyed by a burn, and in which healing had not advanced so far as to renew the organ of touch, it was found that no correct discrimination could be made between two spatulas, one of them at a temperature of from 48° to 54°, the other of from 113° to 122°, which were brought into contact with the denuded surface; so that one of these patients thrice affirmed that he was being touched with the cold body, when it was the warm, and the reverse. But when the spatula was in one instance made somewhat warmer, and was brought into contact with the unskinned surface, the patient felt, not *heat* but *pain.* Another means of gaining information on this point, is afforded by the ingestion or injection of a large quantity of warm or cold fluid into the stomach or intestinal canal. Thus Professor Weber states, that after drinking a tumbler of water at 32°, he felt the cold water in the mouth, in the palate, and in the pharynx, as far as the limits of the sense of touch; but that the gradual passage of the cold water into the stomach could not be perceived. There was, it is true, a slight sensation of cold in the gastric region; but as it only occupied the situation of the anterior wall of the stomach, it was attributable to the abstraction of heat from the abdominal integuments in contact with this. In an opposite experiment, the author drank quickly three glasses of milk, the temperature of the first of which was 158°, that of the second 145°, whilst that of the third was intermediate between the two. The sensation of heat could not be traced lower down that that of the cold in the previous experiment. At the moment when the fluid entered the stomach, there was a feeling which remained for some time, but which could not be distinguished as

* "Müller's Archiv.," 1849. Heft iv. s. 273–283.

heat, being mistakeable for cold. In order to ascertain the sensation produced in the large intestine by cold water, an injection of 14 ounces of water of the temperature of 65° was thrown up the rectum; but scarcely any sensation of cold could be perceived from it. In another instance, 21 ounces of water at the same temperature were thrown up, without any resulting sensation of cold. In both these cases, on the return of the enema a few minutes afterwards, a distinct feeling of cold was experienced at the anus. When water of so low a temperature as $45\frac{1}{2}°$ was injected, the first feeling excited was a sensation of cold in the immediate neighbourhood of the anus, and then a feeble movement in the bowels; but a little time afterwards, there was a faint sensation of cold, especially in the anterior wall of the abdomen. This sensation, however, remained after the return of the water; and may hence be attributed to the abstraction of warmth from the abdominal integuments, which was proved to take place, the temperature of the surface being lowered 3°. So, again, if the cavity of the nose be filled with cold water, the coldness is only perceived in the parts of the cavity which are most endowed with the proper tactile sense, namely, the neighbourhood of the nostrils and of the pharynx; and it is not all discernible in the higher part of the cavity, which is especially subservient to the olfactory sense. But when the water injected is very cold (*e, g.* 41°), a peculiar pain is felt in the upper part of the nasal fossæ, extending to the regions of the forehead and the lachrymal canals; this pain, however, is altogether different from the sense of coldness.—From the foregoing experiments it appears fair to conclude, that the sensory nerves have no power of receiving impressions indicative of difference of temperature, unless those impressions are communicated through a special organ; but they afford no adequate ground for the supposition, that a set of nerve-fibres is provided for their transmission, distinct from those which minister to common sensation. This conclusion is confirmed by the fact, that we cannot excite impressions of heat or cold by direct application to the trunks of nerves which we know must conduct such impressions: for the parts of the skin, immediately beneath which lie large nerve-trunks, are not more sensitive to moderate heat or cold than are any others; whilst a greater degree of either is felt as pain, not as a change of temperature. Thus, a mixture of ice and water, applied over the ulnar nerve, affects it in fifteen seconds, and produces severe pain, having no resemblance to cold, such as cannot be excited by the same cold applied to any other region. So the nerve of the tooth-pulp is equally and similarly affected by water of 43° and of 112°; either application causing a pain exactly similar to that excited by the other, or to that produced by pressure. The same is true of the impressions received through the skin itself, when they pass beyond certain limits of intensity; thus, the sensation produced by touching frozen mercury is said to be not distinguishable from that which results from touching a red-hot iron.

867. The improvement in the sense of Touch, in those persons whose dependence upon it is increased by the loss of other senses, is well known; this is doubtless to be in part attributed (as already remarked) to the increased attention which is given to the sensations, and in part, it may be surmised, to an increased development of the tactile organs themselves, resulting from the frequent use of them. The process of the acquire-

ment of the power of recognising elevated characters by the touch, is a remarkable example of this improvability. When a blind person first commences learning to read in this manner, it is necessary to use a large type; and every individual letter must be felt for some time, before a distinct idea of its form is acquired. After a short period of diligent application, the individual becomes able to recognise the combination of letters in words, without forming a separate idea of each letter; and can read line after line, by passing the finger over each, with considerable rapidity. When this power is once thoroughly acquired, the size of the type may be gradually diminished; and thus blind persons may bring themselves, by sufficient practice, to read a type not much larger than that of an ordinary large-print Bible. The case of Saunderson, who, although he lost his sight at two years old, became Professor of Mathematics at Cambridge, is well known; amongst his most remarkable faculties, was that of distinguishing genuine medals from imitations, which he could do more accurately than many connoisseurs in full possession of their senses. Several instances are recorded, of men who became eminent as Sculptors after the loss of their sight, and who were particularly successful in modelling portrait-busts: here, it is obvious, not merely the *tactile* but the *muscular* sensibility must be greatly augmented in acuteness by the habit of attention to it. The power of immediate recognition of individuals by the slightest contact of the hands, even after long periods of time, which most blind and deaf persons have displayed, is one of the most curious examples of the mode in which tactual perceptions will impress themselves on the memory, when they are habitually attended to. As an example of the correct notions which may be conveyed to the mind, of the forms and surfaces of a great variety of objects, and of the sufficiency of these notions for accurate comparison, the Author may mention the case of a blind friend of his own, who has acquired a very complete knowledge of Conchology, both recent and fossil; and who is not only able to recognise every one of the numerous specimens in his own cabinet, but to mention the nearest alliances of a shell previously unknown to him, when he has thoroughly examined it by his touch. Many similar instances might be cited, one of the most remarkable being that of John Gough, who, though blind, was a noted botanical collector, and earned his livelihood as a land-surveyor. Several cases are on record,* of the acquirement, by the blind, of the power of distinguishing the colours of surfaces, which were similar in other respects; and, however wonderful this may seem, it is by no means incredible. For it is to be remembered that the difference of colour depends upon the position and arrangement of the particles composing the surface, which render it capable of reflecting one ray whilst it absorbs all the rest; and it is quite consistent with what we know from other sources, to believe that the sense of Touch may become so refined, as to communicate a perception of such differences.†

* Among the best-authenticated of these, is that of a lady who became blind, and afterwards deaf, in consequence of an attack of confluent small-pox; cited in Dr. Kitto's "Lost Senses," vol. ii. p. 79, from the "Annual Register" for 1758.—Dr. Kitto's treatise may be referred-to, as containing a large collection of interesting cases of a similar description.

† For some additional details in regard to the sense of Touch, see the Author's article 'Touch' in the "Cyclopædia of Anatomy and Physiology," vol. iv.

### 3. *Sense of Taste.*

868. The sense of Taste is that by which we distinguish the *sapid* properties of bodies. The term, as commonly understood, includes much more than this; being usually employed to designate the whole of that knowledge of the qualities of a body (except such as is purely tactile), which we derive through the sensory apparatus situated within the mouth. But it will be hereafter shown that a considerable part of this is dependent upon the assistance of the *olfactive* sense; which is affected, through the posterior nares, by the odorous emanations of all such bodies as are capable of giving them off; and the indications of which are so combined with those of the true gustative sense, as to make an apparently single impression upon the sensorium. Moreover, there are certain sensorial impressions received through the organ of taste, which are so nearly allied in their character to those of *touch*, as to render it difficult to specify any fundamental difference between them: such are the *pungent* sensations produced by mustard, pepper, the essential oils, &c.; all of which substances produce a sensation when applied for a sufficient length of time to any part of the cutaneous surface, which can scarcely be distinguished from that excited through the organ of taste, in any other way than by its inferior intensity, and by the absence of the concurrent odorous emanations. The *taste* of such substances might, perhaps, be considered, therefore, as the composite result of the impressions made upon the sensorium through a refined and acute *touch*, and by the effect of their odorous emanations upon the organ of *smell*. After making full allowance, however, for all such as can be thus accounted-for, there remains a large class of pure *sapors*, of which we take cognizance without the assistance of smell, and which are altogether dissimilar to any tactile impressions: such are the bitter of quinine, the sour of tartaric acid, the sweet of sugar, the saline of common salt, &c. The smell can give us no assistance in distinguishing small particles of these bodies, since they are either entirely inodorous, or so nearly so as only to be recognizable through its means when in large masses; and the most refined touch cannot afford any indication of that kind of difference among them, of which we are at once rendered cognizant by taste. — Of all the 'special' senses, however, that of Taste is most nearly allied to that of touch, as appears from several considerations. In the first place, the *actual contact* of the object of sense with the organ through which the impression is received, is necessary in the present case, as in the preceding. Again, it appears from the considerations formerly adduced (§ 717), that there is no special nerve of Taste; for the gustative impressions upon the front of the tongue are conveyed by the Lingual branch of the 5th Pair, which also ministers to common sensibility; whilst those made upon the back of the organ are conveyed by the Glosso-pharyngeal, which also ministers to common sensibility; and pressure on the trunk of either of these nerves gives rise to pain, which is not the case with either the olfactory, the optic, or the auditory nerves. Moreover, the papillary apparatus, through which the gustative impressions are made upon the extremities of these nerves, is essentially the same in structure with that of the skin. — But for the gustative nerve-fibres to be impressed by the distinctive

properties of sapid substances, it seems requisite that these substances should be brought into immediate relation with them, and that they should penetrate, in the state of solution, through the investments of the papillæ, into their substance. This would seem to be proved by the two following facts : first, that every substance which possesses a distinct taste is more or less soluble in the fluids of the mouth, whilst substances which are perfectly insoluble do not make their presence known in any other way than through the sense of touch; and, second, that if the most sapid substance be applied in a dry state to the papillary surface, and this be also dry, no sensation of taste is excited. Hence it may be inferred that, in the reception of gustative impressions, a change is produced in the molecular condition of the nerve-fibres, or, to use the language of Messrs. Todd and Bowman, their polarity is excited, by the direct agency of the sapid matter itself. This change may be induced, however, both by electrical and mechanical stimulation. If we make the tongue form part of a galvanic circuit, a peculiar sensation is excited, which is certainly allied rather to the gustative than to the tactile, and which does not seem to be due (as was at one time supposed) to the decomposition of the salts of the saliva. And, as Dr. Baly has pointed out,* "if the end of the finger be made to strike quickly, but lightly, the surface of the tongue at its tip, or its edge near the tip, so as to affect not the substance of the organ, but merely the papillæ, a taste sometimes acid, sometimes saline, like the taste produced by electricity, will be distinctly perceived. The sensation of taste thus induced will sometimes continue several seconds after the application of the mechanical stimulus." On the other hand, as Wagner has truly remarked, if the surface of the tongue near the root be touched with a clean dry glass rod, or a drop of distilled water be placed upon it, a slightly bitterish sensation is produced; and this, if the pressure be continued, passes into that of nausea, and if the pressure be increased, even excites vomiting. The feeling of nausea may be excited by mechanical irritation of any part of the surface of the fauces and soft palate; and this feeling is certainly much more allied to that of taste than to that of touch. Further, it has been observed by Henlé, that if a small current of air be directed upon the tongue, it gives rise to a cool saline taste like that of saltpetre. Thus we find that the peculiar effects of sapid substances upon the nerves of taste may be imitated to a certain extent by other agencies : and it also appears that the sensations excited by these vary according to the part of the gustative surface on which they operate; mechanical or electrical stimulation of the front of the tongue giving rise to a kind of saline taste, whilst mechanical stimulation applied to the back of the tongue and fauces excites the feelings of bitterness and nausea. — One of the conditions requisite for the due exercise of the gustative sense, is a temperature not departing far on either side from that which is natural to the body. It appears from the recent experiments of Prof. E. H. Weber,† that if the tongue be kept immersed for nearly a minute in water of about 125°, the taste of sugar brought in contact with it, either in powder or solution, is no longer perceived; the sense of touch, usually so delicate at the tip of the tongue, being also rendered imperfect. A similar imper-

* Translation of "Müller's Physiology," p. 1062, *note*.
† "Müller's Archiv.," 1847, S. 342.

fection of taste and touch was produced by immersing the tongue for the same length of time in a mixture of water and broken ice.

869. The surface of the tongue is undoubtedly the special seat of gustative sensibility in Man; though the sense of Taste is not by any means restricted to that organ, being diffused in a less degree over the soft palate, the arches of the palate, and the fauces. It is on the Tongue alone, however, that the papillary apparatus is fully developed; and its structure has been so carefully examined and described by Messrs. Todd and Bowman,* that little remains to be added to their account of it.—The lingual papillæ may be divided, in the first place, into the *Simple* and the *Compound;* the former of which had previously escaped observation, through not forming any apparent projection. The *Simple* papillæ are scattered in the intervals of the compound, over the general surface of the tongue; and they occupy much of the surface behind the circumvallate variety, where no compound papillæ exist. They are completely buried and concealed beneath the continuous sheet of epithelium, and can only be detected when this membrane has been removed by maceration; they are then found to have the general characters of the cutaneous papillæ, but nerve-tubes have not yet been detected in them. The *Compound* papillæ are visible to the naked eye; and have been classified, according to their shape, into the *circumvallate*, the *fungiform*, and the *filiform*. The *circumvallate* or calyciform papillæ are eight or ten in number, and are situated in a V-shaped line at the base of the tongue. Each consists of a central flattened circular projection of the mucous membrane, surrounded by a tumid ring of about the same elevation, from which it is separated by a narrow circular fissure. The surface of both centre and border is smooth, and invested by scaly epithelium, which conceals a multitude of simple papillæ. The *fungiform* papillæ are scattered singly over the tongue, chiefly upon its sides and tip. They project considerably from the surface, and are usually narrower at their base than at their summit. They contain a complex capillary plexus, the terminal loops of which enter the numerous simple papillæ, that clothe the surface of the fungiform body. Amidst these lie nerve-tubes, which probably have a looped arrangement;† and the epithelium which covers them is so thin, as to allow the red colour of the blood to be seen through it. In this manner they are readily distinguished from the filiform papillæ, among which they lie. The *filiform* papillæ, like the preceding, contain a plexus of capillaries, and a bundle of nerve-fibres, both terminating in loops, which enter the simple papillæ that clothe the surface of the compound body; but instead of being

Fig. 139.

Capillary network of *fungiform papilla* of the Tongue.

* "Physiological Anatomy and Physiology of Man," vol. i. chap. xv.

† The Author, in conjunction with Messrs. Bowman, T. Wharton Jones, and Kiernan, has most carefully examined the mode of termination of the nerves in the fungiform papillæ, with the view of testing the validity of the assertion of Dr. Waller ("Phil. Trans.," 1849) that they have free truncated extremities. No such terminations, however, could be exhibited to them by Dr. Waller; and the conclusion at which they arrived as most probable, has been already stated (§ 343).

covered with a thin scaly epithelium, they are furnished with bundles of long pointed processes, some of which approach hairs in their stiffness and structure. These are immersed in the mucus of the mouth, and may be moved in any direction, though they are generally inclined backwards. — The simple papillæ which occur in an isolated manner, with those which are aggregated in the circumvallate and fungiform bodies, doubtless minister to the sense of Taste; but there seems much reason to coincide in the opinion of Messrs. Todd and Bowman, with regard to the different office of the filiform papillæ. "The comparative thickness of their protective covering, the stiffness and brush-like arrangement of their filamentary productions, their greater development in that portion of the dorsum of the tongue which is chiefly employed in the movements of mastication, all evince the subservience of these papillæ to the latter function, rather than to that of taste; and it is evident that their isolation and partial mobility on one another, must render the delicate touch with which they are endowed, more available in directing the muscular actions of the organ. The almost manual dexterity of the organ, in dealing with minute particles of food, is probably provided-for, as far as sensibility conduces to it, in the structure and arrangement of these papillæ." It may be added, that the filiform papillæ of Man seem to be the rudimentary forms of those horny epithelial processes, which acquire so great a development in the tongues of the Carnivora, and which are of such importance in the abrasion of their food.

870. The simple application of a sapid substance to the gustative surface, is usually sufficient to excite the sensation; and if this application be restricted to one particular spot, we are able to recognize its place more or less distinctly. In this respect, then, the gustative impression resembles the tactile; for whilst we cannot, by our own consciousness, distinguish the parts of the retina or of the auditory apparatus on which visual or auditory impressions are made, we can make this distinction in regard to the surface which is supplied by the nerves of general sense. This determination is most precise when the impression is made on the parts of the tongue of which the gustative sensibility is most acute; namely, the apex, sides, and posterior part of the dorsum; being probably aided, however, near the tip, by the acuteness of its tactile sensibility. The impressibility of the middle portion of the dorsum is greatly inferior; but still, when the gustative sensation has been excited there, it is referred to the spot on which the sapid substance was laid. The contact of sapid substances much more readily excites a gustative sensation, when it is made to press upon the papillæ, or is moved over them. Thus there are some substances whose taste is not perceived when they are simply applied to the central part of the dorsum of the tongue, but of whose presence we are at once rendered cognizant by pressing the tongue against the roof of the mouth. The full flavour of a sapid substance, again, is more readily perceived when it is rubbed on any part of the tongue, than when it is simply brought in contact with it, or pressed against it. Even when liquids are received into the mouth, their taste is most completely discriminated by causing them to move over the gustative surface: thus the "wine-taster" takes a small quantity of the liquor into his mouth, carries it rapidly over every part of its lining membrane, and then ejects it. It is not improbable

that this exaltation of the usual effects is simply due to mechanical causes; the sapid particles being brought by the pressure or movement into more rapid and complete operation on the nerve-fibres, than they would be if simply placed in contact with the papillæ.—The impressions made upon our consciousness by a large proportion of sapid substances are of a complex kind; being in part derived from their odorous emanations, of which we take cognizance through the organ of Smell. Of this any one may convince himself, by closing the nostrils, and inspiring and expiring through the mouth only, whilst holding in the mouth, or even rubbing between the tongue and the palate, some aromatic substance; for its taste is then scarcely recognized, although it is immediately perceived when its effluvia are drawn into the nose. It is well known too, that, when the sensibility of the Schneiderian membrane is blunted by inflammation (as in an ordinary cold in the head), the power of distinguishing flavours is very much diminished. In fact, some Physiologists are of opinion that *all* our knowledge of the *flavour* of sapid substances is received through the Smell; but this, as already shown, would not be a correct statement; and there are cases on record in which the sense of Smell has been entirely lost, without any impairment of the true sense of Taste.*

871. Taken in its ordinary compound acceptation, the sense of Taste has for its object to direct us in the choice of food, and to excite the flow of mucus and saliva, which are destined to aid in the preparation of the food for Digestion. Among the lower Animals, the instinctive perceptions connected with this sense are much more remarkable than our own; thus an omnivorous Monkey will seldom touch fruits of a poisonous character, although their taste may be agreeable; and animals, whose diet is restricted to some one kind of food, will decidedly reject all others. As a general rule it may be stated, that substances of which the taste is agreeable to us, are useful in our nutrition, and *vice versâ*;† but there

* An interesting case of this kind, occurring in a Negro who had gradually lost the characteristic hue of his skin, and had acquired the fair complexion of a European, has lately been put on record by Dr. J. C. Hutchison.—The Olfactory nerve seemed to be entirely paralysed, whilst the branches of the 5th Pair retained their integrity; so that, whilst the proper sense of Smell was entirely lost, a pungent burning sensation was excited by irritating vapours, and the application of snuff induced sneezing. Notwithstanding this deficiency, the sense of Taste, properly so called, did not seem to be impaired; for substances which neither possessed odour nor pungency could be readily discriminated, even though their tastes were not widely different. (See "Amer. Journ. of Med. Sci.," Jan. 1852).

† It is justly remarked by Dr. Holland ("Medical Notes and Reflections," p. 85), that,—"In the majority of instances of actual illness, provided the real feelings of the patient can be safely ascertained, his desires as to food and drink may be safely complied with. But undoubtedly much care is needful that we be not deceived as to the state of the appetites, by what is merely habit or wrong impression on the part of the patient, or the effect of the solicitation of others. This class of sensations is more nurtured out of the course of nature, than are those which relate to the temperature of the body. The mind becomes much more deeply engaged with them; and though in acute illness they are generally submitted again to the natural law, there are many lesser cases where enough remains of the leaven of habit to render every precaution needful. With such precautions, however, which every physician who can take schooling from experience will employ, the stomach of the patient becomes a valuable guide; whether it dictate abstinence from a recurrence of food; whether much or little in quantity; whether what is solid or liquid; whether much drink or little; whether things warm or cold; whether sweet, acid, or saline; whether bland or stimulating to the taste." Further, Dr. Holland remarks: "It is not wholly paradoxical to say that we are authorized to give greatest heed to the stomach when it suggests some seeming extravagance of diet. It may be that this is a mere depravation of the sense of taste; but frequently it

are many signal exceptions to this.—Like other senses, that of Taste is capable of being rendered more acute by education; and this on the principles already laid down in regard to Touch. The experienced wine-taster can distinguish differences in age, purity, place of growth, &c., between liquors that to ordinary judgments are alike; and the epicure can give an exact determination of the spices that are combined in a particular sauce, or of the manner in which the animal, on whose flesh he is feeding, was killed. As in the case of other senses, moreover, impressions made upon the sensory surface remain there for a certain period; and this period is for the most part longer than that which is required for the departure of the impressions made upon the eye, the ear, or the organ of smell. Every one knows how long the taste of some powerful substances remains in the mouth; and even of those which make less decided impressions, the sensations remain to such a degree that it is difficult to compare them at short intervals. Hence if a person be blindfolded, and be made to taste substances of distinct, but not widely-different flavours (such as various kinds of wine or of spirituous liquors), one after another in rapid succession, he soon loses the power of discriminating between them. In the same manner, the difficulty of administering very disagreeable medicines may be sometimes got-over, by either previously giving a powerful aromatic, or by combining the aromatic with the medicine; its strong impression in both cases preventing the unpleasant taste from exciting nausea.

### 4.—*Sense of Smell.*

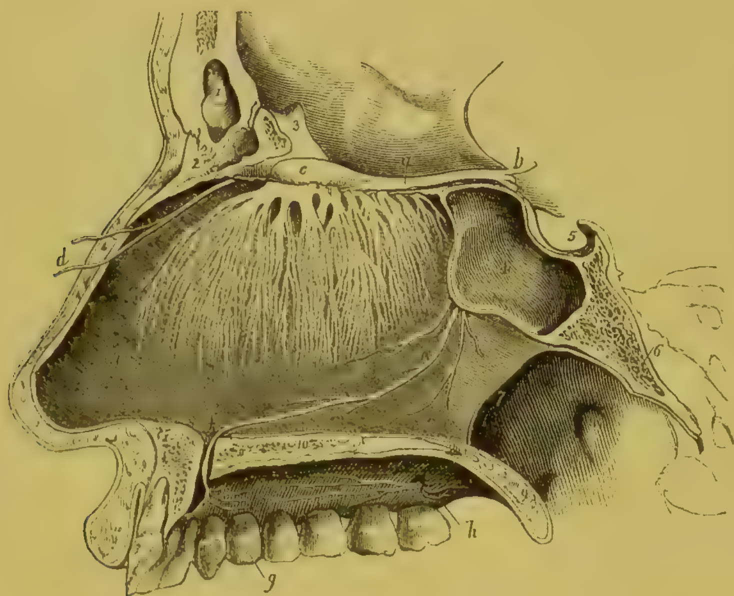
872. Of the nature of Odorous emanations, the Natural Philosopher is so completely ignorant, that the Physiologist cannot be expected to give a definite account of the mode in which they produce sensory impressions. Although it may be surmised that they consist of particles of extreme minuteness, dissolved as it were in the air, and although this idea seems to derive confirmation from the fact that most odorous substances are volatile, and *vice versâ*,—yet the most delicate experiments have failed to discover any diminution in weight, in certain substances (as musk) that have been impregnating with their effluvia a large quantity of air for several years; and there are some volatile fluids, such as water, which are entirely inodorous. The true Olfactory nerves pass down from the Olfactory Ganglion (§ 729) in the form of very numerous minute threads, which form a plexus upon the surface of the Schneiderian or pituitary membrane. The filaments composing this plexus are described by Messrs. Todd and Bowman* as differing widely from those of the ordinary cephalic

expresses an actual need of the stomach, either in aid of its own functions, or indirectly (under the mysterious law just referred-to) for the effecting of changes in the whole mass of blood. It is a good practical rule in such cases to withhold assent, till we find after a certain lapse of time that the same desire continues or strongly recurs; in which case it may generally be taken as the index of the fitness of the thing desired for the actual state of the organs. In the early stage of recovery from long gastric fevers, I recollect many curious instances of such contrariety to all rule being acquiesced-in, with manifest good to the patient. Dietetics must become a much more exact branch of knowledge, before we can be justified in opposing its maxims to the natural and repeated suggestions of the stomach, in the state either of health or disease."

* "Physiological Anatomy," vol. ii. p. 9.

nerves in structure; they contain no white substance of Schwann, are nucleated and finely granular in texture, and altogether bear a close resemblance to the gelatinous form of nerve-fibres. It has been hitherto found impossible to trace the ultimate distribution of these fibres in the olfactory membrane, owing to their want of the characteristic white substance, and the absence of distinction between the nuclei of the minuter

Fig. 140.



Distribution of the *Olfactory Nerve* on the Septum Nasi. The nares have been divided by a longitudinal section made immediately to the left of the septum, the right nares being preserved entire.—1. The frontal sinus. 2. The nasal bone. 3. The crista galli process of the ethmoid bone. 4. The sphenoidal sinus of the left side. 5. The sella turcica. 6. The basilar process of the sphenoid and occipital bones. 7. The posterior opening of the right nares. 8. The opening of the Eustachian tube in the upper part of the pharynx. 9. The soft palate, divided through its middle. 10. Cut surface of the hard palate. *a.* The olfactory peduncle. *b.* Its three roots of origin. *c.* Olfactory ganglion, from which the filaments proceed that spread out in the substance of the pituitary membrane. *d.* The nasal nerve, a branch of the ophthalmic nerve, descending into the left nares from the anterior foramen of the cribriform plate, and dividing into its external and internal branch. *e.* The naso-palatine nerve, a branch of the spheno-palatine ganglion distributing twigs to the mucous membrane of the septum nasi in its course to (*f*) the anterior palatine foramen, where it forms a small gangliform swelling (Cloquet's ganglion) by its union with its fellow of the opposite side. *g.* Branches of the naso-palatine nerve to the palate. *h.* Posterior palatine nerves. *i, i.* The septum nasi.

fibres and those of the nucleated tissues through which they pass. It would appear that every part of the Schneiderian membrane is not equally endowed with the faculty of distinguishing *odours*, which is a very different power from that of becoming sensible of irritation from them. The distribution of the Olfactory nerves seems limited to the membrane covering the superior three-fourths of the septum of the nose, the superior turbinated bone and the upper half of the middle turbinated bone, and the upper wall of the nasal cavities beneath the cribriform plate of the ethmoid bone; all which surface is covered (as Messrs. Todd and Bowman have pointed out) with a tesselated epithelium of a rich sepia-brown hue. The remainder of the nasal surface is supplied by the 5th Pair only; and hence it is that we cannot distinguish faint odours, unless, by a peculiar inspiratory effort, we draw the air charged with them to the upper part of the nose. In animals living in the air, it is a necessary condition of the exercise of the sense of Smell, that the odorous

matter should be transmitted by a respiratory current through the nostrils; and that the membrane lining these should be in a moist state. Hence, by breathing through the mouth, we may avoid being affected by odours even of the strongest and most disagreeable kind; and in the first stage of a catarrh, when the ordinary mucous secretion is suspended, the sense of Smell is blunted from this cause, as it afterwards is from the excess in the quantity of the fluid, which prevents the odoriferous effluvia from coming into immediate relation with the sensory extremities of the nerves. Hence we may easily comprehend how section of the 5th Pair, which exerts a considerable influence over the secretions, will greatly diminish the acuteness of this sense, and will have the further effect of preventing the reception of any impressions of irritation from acrid vapours, which are entirely different in their character from true odorous impressions, and are not transmitted through the Olfactory nerve (§ 739). The nasal passages may indeed be considered as having, in the air-breathing Vertebrata, two distinct offices; they constitute the organ of Smell, through the distribution of the olfactory nerve upon a part of their surface; but they also constitute the portals of the respiratory organs, having for their office to take cognizance of the aeriform matter which enters them, and to give warning of that which would be injurious; this latter function is performed by the 5th Pair, as by the Pneumogastric in the glottis. It is through this nerve that the act of Sneezing is excitable; the evident purpose of which, is the ejection of a strong blast of air through the nasal passages, in such a manner as to drive out any offending matter they may contain.

873. The importance of the sense of Smell among many of the lower Animals, in guiding them to their food, or in giving them warning of danger, and also in exciting the sexual feelings, is well known. To Man its utility is comparatively small under ordinary circumstances; but it may be greatly increased when other senses are deficient. Thus, in the well-known case of James Mitchell, who was deaf, blind, and dumb, from his birth, it was the principal means of distinguishing persons, and enabled him at once to perceive the entrance of a stranger. It is recorded that a blind gentleman, who had an antipathy to cats, was possessed of a sensibility so acute in this respect, that he perceived the proximity of one that had been accidentally shut up in a closet adjoining his room. Among Savage tribes, whose senses are more cultivated than those of civilized nations, more direct use being made of the powers of observation, the scent is almost as acute as in the lower Mammalia; it is asserted by Humboldt, that the Peruvian Indians in the middle of the night can thus distinguish the different races, whether European, American-Indian, or Negro.*—The agreeable or disagreeable character assigned to particular odours, is by no means constant amongst different individuals. Many of the lower Animals pass their whole lives in the midst of odours, which are to Man (in his civilized condition at least) in the highest degree revolting; and will even refuse to touch food, until it is far advanced in putridity. It more frequently happens in regard to odours and savours,

* The Author has been assured by a competent witness, that a youth in the state of Hypnotism had his sense of Smell so remarkably heightened, as to be able to assign (without the least hesitation) a glove placed in his hand, to its right owner,—in the midst of about thirty persons, the boy himself being blindfolded.

than with respect to other sensory impressions, that habit makes that agreeable, and even strongly relished, which was at first avoided; the taste of the epicure for game that has acquired the *fumet*,—for olives,—for asafœtida, &c. are instances of this. As to the length of time during which impressions made upon the organ of smell remain upon it, no certain knowledge can be obtained. It is difficult to say when the effluvia have been completely removed from the nasal passages, since it is not unlikely that the odorous particles (supposing such to exist) are absorbed or dissolved by the mucous secretion; it is probably in this manner that we may account for the fact, well known to every medical man, that the cadaverous odour is frequently experienced for days after a post-mortem examination.*

### 5.—*Sense of Vision.*

874. The objects of this sense are bodies, which are either in themselves luminous, or which become so by reflecting the light that proceeds from others. Whether their light is transmitted by the actual emission of luminous particles, or by the propagation of undulations analogous to those of sound, is a question that has been long keenly debated amongst Natural Philosophers; but it is of little consequence to the Physiologist which is the true solution, since it is only with the laws according to which the transmission takes place, that he is concerned. These laws it may be desirable here briefly to recapitulate.

875. Every point of a luminous body sends off a number of rays, which diverge in every direction, so as to form a cone, of which the luminous point is the apex. So long as these rays pass through a medium of the same density, they proceed in straight lines; but, if they enter a medium of different density, they are *refracted* or bent,—*towards* the perpendicular to the surface at the point at which they enter, if they pass from a rarer into a denser medium, and *from* the perpendicular, when they pass from a denser medium into a rarer. It is easily shown to be a result of this law, that, when parallel rays passing through air fall upon a convex surface of glass, they will be made to converge; so as to meet at the opposite extremity of the diameter of the circle, of which the curve forms part. If, instead of continuing in the glass, they pass out again, through a second convex surface, of which the direction is the reverse of the first, they will be made to converge still more, so as to meet in the centre of curvature. Rays which are not parallel, but which are diverging from a focus, are likewise made to converge to a point or focus; but this point will be more distant from the lens, in proportion as the object is nearer to it, and the angle of divergence consequently greater. The rays diverging from the several points of a luminous object, are thus brought to a corresponding focus; and the places of all these foci hold exactly the same relation to each other, with that of the points from which the rays diverged; so that a perfect image of the object is formed upon a screen held in the focus of the lens. This image, however, will be inverted; and its size, in proportion to that of the object, will depend upon their respective distances from

* This may partly be attributed also to the effluvia adhering to the dress. It has been remarked that *dark* cloths retain these more strongly than light.

ie lens. If their distances be the same, their size will also be the same; if the object be distant, and the image near, the latter will be much the smaller; and *vice versâ*.

876. There are two circumstances, however, which interfere with the perfection of an image thus formed by a convex lens. The one is, that, if the lens constitute a large part of the sphere from which it is taken, the rays which fall near its margin are not brought to a focus at the same point with those which pass through its centre, but at a point nearer the lens. This difference, which must obviously interfere greatly with the distinctness of the image, is termed *Spherical Aberration;* it may be corrected by the combination of two or more lenses, of which the curvatures are calculated to balance one another, in such a manner that all the rays shall be brought to the same focus; or by diminishing the aperture of the lens by means of a stop or diaphragm, in such a manner that only the central part of it shall be used. The latter of these methods is the one employed, where the diminution in the amount of light transmitted is not attended with inconvenience. The nearer the object is to the lens (and the greater, therefore, the angle of divergence of its rays), the greater will be the spherical aberration, and the more must the aperture of the diaphragm be contracted in order to counteract it.—The other circumstance that interferes with the distinctness of the image, is the unequal refrangibility of the differently-coloured rays, which together make up white or colourless light; the violet being more bent from their course than the blue, the blue more than the yellow, and the yellow more than the red; the consequence of which will be, that the violet rays are brought to a focus much nearer to the lens than the blue, and the blue nearer than the red. If a screen be held to receive the image, in the focus of any of the rays, the others will make themselves apparent as fringes round its margin. This difference is termed *Chromatic Aberration.* It is corrected in practice, by combining together lenses of different substances, of which the *dispersive* power (that is, the power of separating the coloured rays) differs considerably. This is the case with flint and crown glass, for instance,—the dispersive power of the former being much greater than that of the latter, whilst its refractive power is nearly the same: so that, if a convex lens of crown glass be united with a concave of flint whose curvature is much less, the dispersion of the rays effected by the former will be entirely counteracted by the latter, which diminishes in part only its refractive power.

877. The Eye may be regarded as an optical instrument of great perfection, adapted to produce, on the expanded surface of the Optic nerve, a complete image or picture of luminous objects brought before it; in which the forms, colours, lights and shades, &c. of the object are all accurately represented. By the different refractive powers of the transparent media through which the rays of light pass, and by the curvatures given to their respective surfaces, both the Spherical and Chromatic aberrations are corrected in a degree sufficient for all practical purposes; so that, in a well-formed eye, the picture is quite free from haziness and from false colours. The power by which it adapts itself to variations in the distance of the object,—so as to form a distinct image of it, whether it be six inches, six yards, or six miles off,—is extremely remarkable, and cannot be regarded as hitherto completely explained. It is obvious that, if we fix upon any

distance as that for which the eye is naturally adjusted (say 12 or 14 inches, the distance at which we ordinarily read), the rays proceeding from an object placed nearer to the eye than this, would not be brought to a focus upon the retina, but would converge towards a point behind it; whilst, on the contrary, the rays from an object at a greater distance would meet before they reached the retina, and would have again diverged from each other when they impinge upon it; so that, in either case, vision would be indistinct. Now two methods of adaptation suggest themselves to the Optician. Either he may vary the distance between the refracting surface and the screen on which the image is formed, in such a manner, that the latter shall always be in the focus of the converging rays; or, the distance of the screen remaining the same, he may vary the convexity of his lens, in such a manner as to adapt it to the distance of the object. The mode in which this adaptation is effected in the Human Eye has not yet been clearly made out; and many hypotheses have been put forward respecting it. According to the calculations of Olbers, based on the ascertained refractive powers of the media of the eye, the difference between the focal distances of the images of two objects, the one so far off that its rays are parallel, and the other at the distance of only four inches from the eye, is about 0·143 or one-seventh of an inch; but as the usual range of distinct vision does not extend to objects brought within six or seven inches, the amount of change required in the relative places of the refracting bodies and the retina, would not ordinarily exceed a line. It has been thought that this change might be produced by an alteration in the convexity of the cornea, or by an elongation of the globe of the eye generally, or by both methods in combination; which alterations, it was supposed, might be effected by the action of the muscles of the eye-ball. But no such changes have been detected by the most careful measurement; and it cannot be shown *how* any contractile action of the muscles of the eye-ball could produce an elongation of the eye, since their tendency would be (when acting altogether) to draw it backwards into its socket, or, this being prevented by the fascia and cushion of fat against which its posterior side rests, to flatten the globe against this, rather than to increase its projection. There is much more ground for the belief, however, that a change of place is effected in the crystalline lens, by the action of the ciliary muscle and the erectile tissue of the ciliary processes; for, although no such change can be demonstrated by observation, yet it can be shown that the contraction of the ciliary muscle would tend to draw the lens forwards; and the fact that this muscle is peculiarly powerful in the predaceous birds, which are distinguished for their great range of vision, and which have, in their circle of osseous sclerotic plates, an unusually firm point of attachment for it, is a strong argument in favour of this doctrine.* Further, the almost entire loss of the power of adapting the eye to distances, which is experienced after the removal of the Crystalline lens in the operation for Cataract, is a marked indication that some change in the place or figure of this body is the principal means whereby the ordinary adaptation is effected; and although it has been suggested that an alteration in the figure of the lens might participate in the result, yet no means can be

* See on this subject, Messrs. Todd and Bowman's "Physiological Anatomy," vol. ii. p. 27; and Dr. Clay Wallace on "The Adjustment of the Eye to Distances," New York, 1851.

pointed-out as competent to produce it; so that, as far as we can at present judge, a change in the *place* of the lens is the sole means of adapting the eye to distinct vision at varying distances.—It is certain that the condition of *repose* is that of vision for *distant* objects, no fatigue being experienced from the prolonged direction of the eye to these; whilst the employment of the visual power upon *near* objects for some time, is accompanied with a sense of *effort*, and is followed by fatigue. The movement which effects the change of place of the crystalline lens is performed in obedience to Volition and is guided by sensation; yet we are not conscious of performing it, all that we *will* being the *result;* and thus we have another apposite illustration of the really automatic nature of what are termed voluntary movements generally (§ 757).

878. When both eyes are fixed upon an object, their axes converge so as to meet in it; and the degree of convergence is of course altered by variations in the distance of the object; since, when the object is very remote, the optic axes are virtually parallel, whilst its approach causes them to incline towards each other, and this the more rapidly as the object is brought nearer, the increase being the greatest when it has arrived within the ordinary distance of distinct vision. Here, again, we have an example of the automatic nature of voluntary actions; for the convergence of the eyes that may be produced by such a gradual approximation of an object on which the eyes are kept fixed by an effort of the Will, far exceeds that which most individuals can induce by an effort made directly for the purpose; and if, when an object has thus been gradually approximated to within a few inches of the nose, the effort be intermitted and the optic axes be allowed to regain their parallelism, they can seldom be brought to converge again upon it, without repeating the whole process.—It has been thought, from the close accordance between the changes required for the adaptation of the eyes to distinct vision at different distances, and the alterations in the direction of the optic axes which are required to bring the two eyes to bear upon objects at varying degrees of proximity or remoteness, that the former of these movements is in some degree dependent upon the latter, or, at any rate, that the two proceed from a common motor impulse. But that the convergence of the axes is not itself in any way the occasion of the alteration of the focus of the eye, is shown by these two facts; first, that the adaptation is as perfect in a person who only possesses or uses one eye, as it is when both are employed; and second, that some persons possess the power of altering the focus of the eye by an effort of the will, whilst the convergence remains the same.—In regard to the adaptation of the eyes to varying distances, it is further to be remarked, that, when an object is being viewed as near to the eye as it can be distinctly seen, the pupil contracts in a considerable degree. The purpose of this change, is evidently to exclude the outer rays of the cone or pencil, which, from the large angle of their divergence, would fall so obliquely on the convex surface of the eye, as to be much affected by the spherical aberration; and thus to allow the central rays only to enter the eye, so as to preserve the clearness of the image. The channel through which it is effected is evidently the same as that by which the convergence of the eyes is produced,—namely, the inferior branch of the 3rd Pair of nerves; to the action of which, the sensations received through the retina form the immediate stimulus, in the same

manner as they do to the ordinary variation in the diameter of the pupil under the influence of light; but the voluntary determination to fix the vision upon the object, is the original source of the action.

879. The ordinary forms of defective vision, which are known under the names of *Myopia* and *Presbyopia*, or 'short-sightedness' and 'long-sightedness,' are entirely attributable to defects in the optical adaptation of the eye. In the former, its refractive power is too great; the rays from objects at the usual distance are consequently brought too soon to a focus, so as to cross one another and diverge before they fall upon the retina; whilst the eye is adapted to bring to their proper focus on the retina, only those rays which were previously diverging at a large angle, from an object in its near proximity. Hence a 'short-sighted' person, whose nearest limit of distinct vision is not above half that of a person of ordinary sight, can see minute objects more clearly; his eyes having, in fact, the same magnifying power which those of the other would possess, if aided by a convex glass that would enable him to see the object distinctly at the shortest distance. But as the myopic structure of the eye incapacitates its possessor from seeing objects clearly at even a moderate distance, it is desirable to apply a correction; and this is done, by simply interposing between the object and the eye a *concave* lens, of which the curvature is properly adapted to compensate for the excess of that of the organ itself.—On the other hand, in the presbyopic eye, the curvature and refractive power are not sufficient to bring to a focus, on the retina, rays which were previously divergent in a considerable or even in a moderate degree; and indistinct vision in regard to all near objects is, therefore, a necessary consequence, whilst distant objects are well seen. This defect is remedied by the use of *convex* lenses, which make up for the deficiency of the curvature. — We commonly meet with myopia in young persons, and with presbyopia in old; but this is by no means the invariable rule; for even aged persons are sometimes 'short-sighted,' and 'long-sightedness' is occasionally met-with amongst the young. In choosing spectacles, for the purpose of correcting the errors of the eye, it is of great consequence not to make an over-compensation; for this has a tendency to increase the defect, besides occasioning great fatigue in the employment of the sight. It may be easily found when a glass of the right power has been selected, by inquiring of the individual whether it alters the apparent size of the objects, or only renders them distinct. If it alter the size (increasing it, if it be a convex lens, and diminishing it, if it be a concave), its curvature is too great; whilst if it do not disperse the haze, it is not sufficiently powerful. In general it is better to employ a glass which somewhat under-compensates the eye, than one which is of a curvature at all too high; since, with the advance of years in elderly persons, a progressive increase in power is required; and, as young persons grow up to adult age, they should endeavour to dispense with the aid of spectacles.

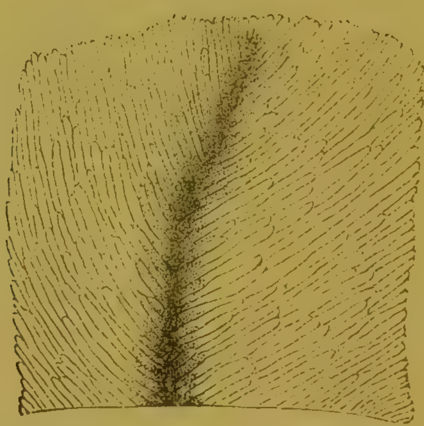
880. Many other interesting inquiries, respecting the action of the Eye as an optical instrument, suggest themselves to the Physical philosopher; but the foregoing are the chief in which the Physiologist is concerned; and we shall now proceed, therefore, to consider the share, which the Nervous apparatus performs in the phenomena of vision.—The Optic Nerve, at its entrance into the eye divides itself into numerous small

fasciculi of ultimate fibrils; and these appear to spread themselves out, and to inosculate with each other by an exchange of fibrils, so as to form a net-like plexus. There is considerable difficulty, however, in the precise determination of the course of the nerve-fibres in the Retina; on account of their minute size, and the absence of their distinctive characters. According to Mr. Bowman,* the tubular membrane and the white substance of Schwann are deficient; and only the central part of the nerve-fibre, or axis-cylinder, is continued into this expansion. The plexus of nerve-fibres comes into relation with a plexus of capillary vessels (Fig. 141), very minutely distributed; and also with a layer of cells, which constitutes the *internal* layer of the true Retina, and which so closely resembles those of the cortical substance of the Brain, that there can be no reasonable doubt of their correspondence in function.† We

FIG. 141.

Distribution of Capillaries in the Vascular layer of the *Retina*.

FIG. 142.



Part of the *Retina of a Frog*, seen from the outer surface, showing the staff-like bodies of 'Jacob's Membrane.'

have here, then, all the elements of an apparatus for the *origination* of changes in the nervous trunks, in a fully developed condition; and it can scarcely be doubted that the essential parts of the same structures exist in connection with the peripheral expansions of the nerves distributed to other sensory organs.—The true Retina is covered externally by a very peculiar investment, the 'Membrane of Jacob,' which separates it from the pigmentary layer. This seems to be composed of cells having a cylindrical form; and these are sometimes arranged vertically to the surface of the membrane, so that their extremities only are seen; whilst in other instances they are found to present an imbricated arrangement, lying over each other obliquely, in which case they are of considerable length (Fig. 142). They are remarkable for the rapidity with which they undergo alterations after death, and especially for the changes in their form which are produced by the action of water.

881. The following statements on the Limits of Human Vision, in

* "Lectures on the Parts concerned in the Operations on the Eye," p. 81.

† This doctrine, which has been taught by the Author for many years, has latterly received full confirmation from the researches of Mr. H. Gray upon the development of the Eye; for he has shown that the Retina is really an offset put-forth (so to speak) from the Optic Ganglion, and that the Optic Nerve is to be considered in the light of a commissure. (See "Philos. Transact.," 1850).

regard to the possible minuteness of the objects of which it can take cognizance, comprehend the result of numerous inquiries made by Prof. Ehrenberg, with the view of calculating the ultimate power of the Microscope.* In opposition to the generally received opinion, Ehrenberg arrived at the conclusion that, in regard to the extreme limits of vision, there is little difference amongst persons of ordinarily good sight, whatever may be the focal distance of their eyes. The smallest square magnitude usually visible to the naked eye, either of white particles on a black ground, or of black upon a white or light-coloured ground, is about the 1-405th of an inch. It is possible, by the greatest condensation of light, and excitement of the attention, to recognize magnitudes between the 1-405th and 1-540th of an inch; but without sharpness or certainty. Bodies which are smaller than these, cannot be discerned with the naked eye when single; but may be seen when placed in a row. Particles which powerfully reflect light, however, may be distinctly seen, when not half the size of the least of the foregoing; thus, gold dust † of the fineness of 1-1125th of an inch, may be discerned with the naked eye in common daylight. The delicacy of vision is far greater for *lines* than for mere points; since opaque threads of 1-4900th of an inch in diameter (about half the diameter of the Silk-worm's fibre) may be discerned with the naked eye, when held towards the light. The degree in which the attention is directed to them, has a great influence on the readiness with which very minute objects can be perceived; and Ehrenberg remarks that there is a much greater difference amongst individuals in this respect, than there is in regard to the absolute limits of vision. Many persons can distinctly see such objects, when their situation is exactly pointed out to them, who cannot otherwise distinguish them; and the same is the case with persons of acuter perception, with respect to objects at distances greater than those at which they can see most clearly. "I myself," says Ehrenberg, "cannot see 1-2700th of an inch, black or white, at twelve inches' distance; but having found it at from four or five inches' distance, I can remove it to twelve inches, and still see the object plainly." Similar phenomena are well known in regard to a balloon or a faint star in a clear sky, or a ship in the horizon: we easily see them after they have been pointed out to us; but the faculty of rapidly descrying depends on the habit of using the eyes in search of such objects, and of attending to the sensory impressions received through them.

882. The amount of light admitted to the Eye is regulated by the contraction and dilatation of the Pupil, which is due to the muscularity of the Iris; its smallest diameter being about 1-20th, and its largest about 1-3rd of an inch. The *converging* fibres of the iris are easily made out, as the membrane is principally composed of them; they have the general characters of the non-striated muscular fibre, but their nuclei are rounder and more loosely attached to the contractile material. Although the principal direction taken by the fibres is from the circumference towards the centre of the iris, yet their course is by no means constantly straight, and they frequently anastomose with each other in their passage;

* Taylor's "Scientific Memoirs," vol. i. p. 576.

† Ehrenberg mentions that he obtained the finest particles of gold, by scraping gilt brass; by filing pure gold, he always obtained much coarser particles.

these anastomoses are most frequent near the pupil. The *circular* fibres of the iris are by no means so distinct; and rarely, in Man, form more than a somewhat undefined band, immediately surrounding the pupil, and lying in front of the radiating fibres. Although the iris is so vascular, that some anatomists have endeavoured to explain its movements on the hypothesis that they constitute a sort of erection, there is no ground for this idea; and it is more plainly demonstrated in many of the lower animals than it is in Man, that the movements of the Iris are truly muscular, since we find the annular as well as the radiating fibres very distinct, and in Birds (many of which seem to possess a power of voluntarily regulating the diameter of the pupil) the former are striated. The contraction of the annular fibres, whereby the diameter of the pupil is diminished, is effected, as already explained (§ 724), through the instrumentality of the 3rd Pair of nerves; the contraction of the radiating fibres, on the other hand, whereby the pupil is dilated, is under the government of the Sympathetic (§ 847). The contraction of the Pupil takes place, as we have seen, not merely for the purpose of excluding superfluous light from the eye, but also that the most divergent rays may be cut off, when the object is brought near the convex surface (§ 878).

883. The sense of Vision depends, in the first place, on the transference to our minds of the picture which is formed upon the retina; this picture puts us in possession of the outlines, lights and shades, colours, and relative positions, of the objects before us; and all the ideas respecting the real forms, distances, &c., of bodies, which we found upon these data, must be considered in the light of *perceptions*, either instinctive or acquired. Many of these are derived through the combination, in our minds, of the Visual sensations, with those derived from the sense of Touch. Thus, to take a most simple illustration, the idea of *smoothness* is one essentially tactile; and yet it constantly occurs to us, on looking at a surface which reflects light in a particular manner. But, if it were not for the association, which experience leads us to form, of the connection between *polish* as seen by the *eye*, and *smoothness* as felt by the *touch*, we should not be able to determine, as we now can do, the existence of both these qualities, from an impression communicated to us through either sense singly. The general fact that, in Man, the greater part of those notions of the external world, by which his actions in the adult state are guided, are acquired by the gradual association of the perceptions derived through the Sight and through the Touch, is substantiated by amply-sufficient evidence. This evidence is chiefly derived from observations made upon persons born blind, to whom sight has been communicated by an operation, at a period of life which enabled them to give an accurate description of their sensations. The case recorded by Cheselden is one of the most interesting of these. The youth (about twelve years of age), for some time after tolerably distinct vision had been obtained, saw everything *flat* as in a picture, simply receiving the consciousness of the impression made upon his retina; and it was some time before he acquired the power of judging, by his sight, of the real forms and distances of the objects around him. An amusing anecdote recorded of him, shows the complete want of natural or intuitive connection which there is in Man, between the ideas formed through visual and through tactile sensations. He was well acquainted with a Dog and a Cat by *feeling*; but

could not remember their respective characters when he *saw* them. One day, when thus puzzled, he took up the Cat in his arms, and felt her attentively, so as to associate the two sets of ideas; and then, setting her down, said, "So, puss, I shall know you another time."—A similar instance has come under the Author's own knowledge; but the subject of it was scarcely old enough to present phenomena so striking. One curious circumstance was remarked of him, which fully confirms (if confirmation were wanting) the view here given. For some time after his sight was tolerably clear, the lad preferred finding his way through his father's house, to which he had been quite accustomed when blind, by touch rather than by sight, the use of the latter sense appearing to perplex rather than to assist him; but, when learning a new locality, he employed his sight, and evidently perceived the increase of facility which he derived from it.—The question has been proposed, whether a person born blind, who was able by the sense of Touch to distinguish a cube from a sphere, would, on suddenly obtaining his Sight, be able to distinguish them by the latter sense. This question was answered by Locke in the negative; and, as appears from the facts just stated, with justice.

884. The actions performed by many new-born animals do not constitute any valid objection to this view; for all that is indicated by them is, that certain sensations give rise to movements adapted to supply the wants to which they relate. Such instinctive actions are, as already pointed out, much more numerous in the lower Animals than in the higher, and in the young of the Human species than in the adult (§ 792); and they do not afford any proof that definite notions, such as we acquire, of the forms and properties of external objects, are possessed by the animals which exhibit them.—We shall now examine, a little more in detail, into the means by which we gain such notions, and the data on which they are founded.

885. The first point to be determined, is one which has been a fruitful source of discussion,—the cause of *Erect Vision*, the picture upon the retina being inverted. Many solutions of it have been attempted; but they are for the most part rather specious than really satisfactory. That which has been of late years the most in vogue, is founded upon what was styled the 'law of visible direction,' which has been supported by Sir D. Brewster, and other eminent Philosophers. This law affirms, that every object is seen in the direction of the perpendicular to that point of the retina, on which its image is formed; or, in other words, that, as all the perpendiculars to the several points of the inner surface of a sphere meet in the centre, the line of direction of any object is identical with the prolonged radius of the sphere, drawn from the point at which its image is made upon the retina. Upon close examination, however, it is found that this law cannot be optically correct; since the lines of direction cross each other at a point much anterior to the centre of the globe; as may be determined by drawing a diagram upon a large scale, and laying down the course of the rays received by the eye, according to the curvatures and refractive powers of its different parts. In this manner it has been determined by Volkmann, that the lines of direction cross each other in a point a little behind the crystalline lens; and that they must thus fall at such different angles on different points of the retina, that no general law can be laid down respecting them. Moreover, even suppos-

ing that such a law were a correct statement of the general fact, it would not afford any real assistance in explaining the phenomenon; since, after all, it is requisite to assume an intuitive application of it, in supposing the mind to derive its ideas of the relative situations of objects from the imagined line of direction. — A much simpler and more direct explanation may be given. We must always bear that in mind, which we have had occasion to notice in regard to all the other Senses, —the broad line of distinction between the *sensation*, and the *perception* or *elementary notion;* the latter being the result of the operation of the Sensory impression on the Cerebrum, but having a nature as distinct as that of any other *effect* can be from that of its *cause.* Further, it has been shown that there is in Man a complete absence of any relation but such as experience developes, between the perceptions derived through the Sight, and those acquired from the Touch. Hence there is no more difficulty in understanding, that an inverted picture upon the retina should convey to us a notion of the external world, which harmonises with that acquired through the sense of touch, than there is in comprehending the existence of any of those intuitive perceptions of animals, which are so much more removed from the teachings of our own experience (§ 792). It is justly remarked by Müller that, "if we do see objects inverted [or rather, if the picture on the retina be inverted] the only proof we can possibly have of it, is that afforded by the study of the laws of Optics; and, if everything is seen reversed, the relative position of the objects remains unchanged. Hence it is, also, that no discordance arises between the sensations of inverted vision and those of touch, which perceives everything in its erect position; for the images of all objects, even of our own limbs, on the retina, are equally inverted, and therefore maintain the same relative position. Even the image of our hand, when used in touch, is inverted." From what has been stated, it would appear quite conceivable, that a person just endowed with sight, should not at first know by his visual powers, whether a pyramid placed before his eyes is the same body, and in the same position, as one with which he has become acquainted by the touch; and, if this be admitted, the inference necessarily follows, that the notion of *erectness*, which we form by the combined use of our eyes and our hands, is really the product of experience in ourselves, whilst it is probably innate or intuitional in the lower Animals.

886. The cause of *Single Vision with the two Eyes* has, in like manner, been the subject of much discussion; since the mode in which we are affected by the two simultaneous impressions, is quite different from that in which we derive our knowledge of external things through the other senses. Some have even asserted, that we do not really employ both eyes simultaneously, but that the mind is affected by the image communicated by one only; and this idea might seem to be confirmed by the fact heretofore mentioned (§ 861), respecting the alternate use of the two eyes, when they are looking through two differently-coloured media. But it is easily disproved in other ways.—It will presently be shown, that all our estimates of the forms of bodies, depend on the combination by the mind, of the images simultaneously transmitted by the two eyes; and our knowledge of distances is in great part obtained in like manner. One condition of Single Vision, however, seems to be this, that the two images of the object should be formed on parts of the two retinæ which are

*accustomed* to act in concert; and *habit* appears to be the chief means by which this conformity is produced. There can be no doubt, however, that double images are continually being conveyed to the Sensorium; but that, from their want of force and distinctness, and from the attention being fixed on something else, we do not take cognisance of them. This may be shown by a very simple experiment. If two fingers be held up before the eyes, one in front of the other, and vision be directed to the more distant, so that it is seen singly, the nearer will appear double; while, if the nearer one be regarded more particularly, so as to appear single, the more distant will be seen double. A little consideration will show, therefore, that our minds must be continually affected with sensations, which cannot be united into the idea of a single image; since, whenever we direct the axes of our eyes towards any object, everything else will be represented to us as double; but we do not ordinarily perceive this, from our minds being fixed upon a clear and distinct image, and disregarding, therefore, the vague undefined images formed by objects at a different focus. Of this it is very easy to convince oneself.—It is moreover evident from this experiment, that double vision cannot result from *want of symmetry* in the position of the images upon the retina, to which some have attributed it; for it answers equally well, if the line of the two fingers be precisely in front of the nose, so that the inclination of both eyes towards either object is equal; the position of the images of the second object must then be at the same distance on either side from the central line of the retina, and yet they are represented to the mind as double. Hence it seems clear that singleness of vision is also dependent upon the convergence of the optic axes in the object to which our gaze is directed. — Attempts have been made to explain the phenomena of Single Vision by the peculiar decussation of the Optic Nerves formerly described (§ 742), it being supposed that only one Optic Ganglion would be affected by an impression made upon both Retinæ. This explanation, however, even supposing the fact to be as stated, would be far from affording the solution of the problem; and it would be entirely inapplicable to that very important series of phenomena to be next described, which show how large an amount of information we derive, not merely from the repetition, but from the difference, of the sensory impressions made by the same object upon our two retinæ; and which indicate that here, as in the case of erect vision, the mental interpretation of the sensory impressions is a process altogether removed from the simple affection of the consciousness by those impressions, and is not to be accounted-for by any structural arrangements of the Sensorial apparatus.

887. We shall next consider the mode, in which our notion of the *solid forms* and relative projection of objects is acquired; on which great light has been thrown by the interesting experiments of Prof. Wheatstone.* It seems perfectly evident, both from reason and experience, that the flat picture upon the retina, which is the immediate source of our sensation, could not itself convey to our minds any notion, but that of a corresponding plane surface. In fact, any notion of *solidity*, which might be formed by a person who had never had the use of more than

* "Philosophical Transactions," 1838 and 1852.

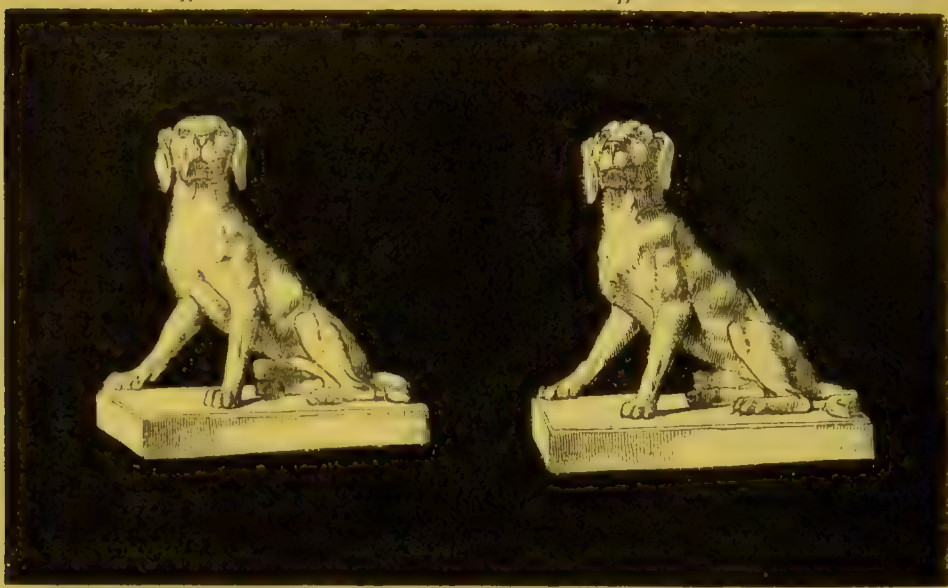
one eye, would entirely depend upon the combination of his visual and tactile sensations. This view is fully confirmed by the case already referred-to, as recorded by Cheselden. The first visual idea formed by the youth was, that the objects around him formed a flat surface, which touched his eyes, as they had previously been in contact with his hands; and after this notion had been corrected, through the education of his sight by his touch, he fell into the converse error of supposing that a picture, which was shown to him, was the object itself represented in relief on a small scale.—But where both eyes are employed, it has been ascertained by Prof. Wheatstone, that they concur in exciting the perception of solidity or projection, which arises from the *mental* combination of the two *dissimilar* pictures formed upon the two retinæ. It is easily shown, that any near object is seen in two different modes by the two eyes. Thus let the reader hold up a thin book, in such a manner that its back shall be exactly in front of his nose, and at a moderate distance from it; he will observe, by closing first one eye and then the other, that his perspective view of it (or the manner in which he would represent it on a plane surface) is very different, according to the eye with which he sees it. With the right eye he will see its right side, very much foreshortened; with the left, he will gain a corresponding view of the left side; and the apparent angles, and the lengths of the different lines, will be found to be very different in the two views. On looking at either of these views singly, no other notion of solidity can be acquired from it, than that to which the mind is conducted, by the association of such a view with the touch of the object which it represents. But it is capable of proof, that the mental association of the two different pictures upon the retinæ, does of itself give rise to the idea of solidity. This proof is afforded by Prof. Wheatstone's ingenious instrument, the Stereoscope, first described by him in 1838.*

888. The *Stereoscope* in its original form essentially consists of two plane mirrors, inclined with their backs to one another at an angle of 90°. If two perspective drawings of any solid object, as seen at a given distance with the two eyes respectively, such as those at A and B, Fig. 143, be so placed before these mirrors, one before each, that their two images shall be made to fall upon the corresponding parts of the two retinæ, in the same manner as the two images formed by the solid object itself would have done, the mind will perceive, not a single representa-

* Various modifications of this instrument have been subsequently introduced; and there is one which has recently (1852) come into very extensive use, in which the two monocular pictures placed side by side, as in Figs. 143, 144, are viewed by the two eyes respectively through two prisms, or two halves of a convex lens. The great advantage of this instrument is its portability; but it is limited to pictures of small size, since the distance between corresponding points of the two pictures must not exceed the distance between the centres of the two eyes; and it is incapable of many adaptations which can be made with the mirror-stereoscope.—As Sir D. Brewster has recently put forth his claim as an original discoverer in regard to the truths of binocular vision which have been established by the Stereoscope, on the strength of some trivial improvements in the construction of the instrument, the Author feels it due to Prof. Wheatstone to state his own conviction, founded upon a careful examination of the whole history of the invention, that the *entire* merit of the *idea*,—that all our perception of solidity derived through the visual sense is consequent upon the mental combination of the two dissimilar pictures upon the two retinæ,—and further, that the whole merit of the *realization* of that idea by means of the mirror-stereoscope, long before Sir D. Brewster's attention had been given to the subject at all,—belongs to Prof. Wheatstone.

tion of the object, nor a confused union of the two, but a projecting or receding surface, the exact counterpart of that from which the drawings were made.* The solid form is forcibly impressed on the mind, even when outlines only are given, especially if these be delineations of simple

Fig. 143.

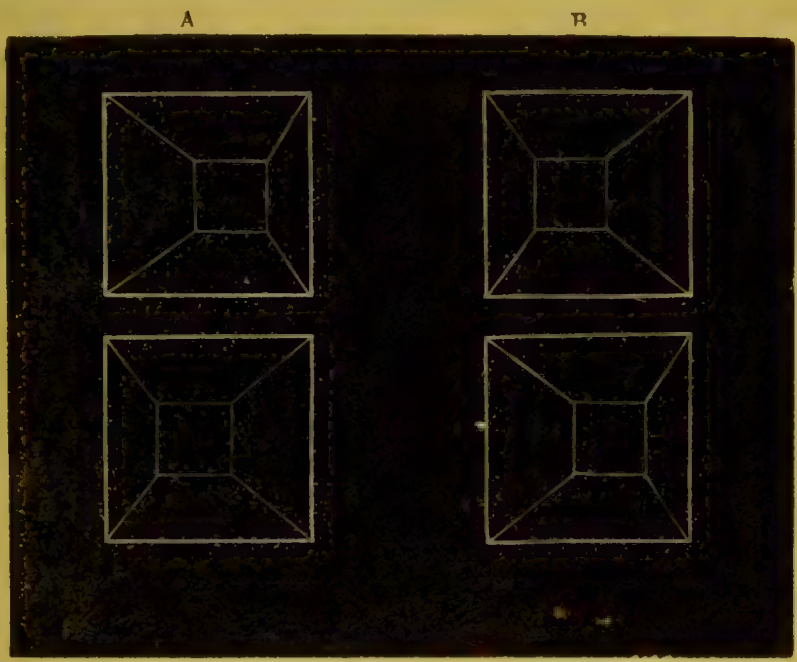



geometrical figures, easily suggested to the mind; and it may be easily shown that the very same outlines will suggest different conceptions, according to the mode in which they are placed. Thus in Fig. 144, the upper pair of figures A, B, when combined in the Stereoscope, convey the idea of a *projecting* truncated pyramid, with the small square *in the centre*, and the four sides sloping equally *away from* it; whilst the lower pair of figures, C, D, which are the same as the upper, but transferred to the opposite sides, no less vividly bring before the mind the visual conception of a *receding* pyramid, still with the small square in the centre, and the four sides sloping equally *towards* it.—Prof. Wheatstone further shows by means of the Stereoscope, that similar images, differing to a certain extent in magnitude, when presented to the corresponding parts of the two retinæ, give rise to the perception of a single object, intermediate in size between the two monocular pictures. Were it not for this, objects would appear single, only when at an equal distance from both eyes, so that their pictures upon the retina are of the same size; which will only happen, when they are directly in front of the median line of the face. Again, if pictures of dissimilar objects be simultaneously presented to the two eyes, the consequence will be similar to that which is experienced, when the rays come to the eye through two differently-coloured media; the two images do not coalesce, nor do they

* The most striking effect is produced by two photographic pictures, taken at the same time by two cameras, so placed that their axes shall form the same angle with each other as that which the axes of the two eyes would form when looking at the same object. This adaptation, though the credit has been assumed by others, was originally devised by Prof. Wheatstone.

ppear permanently superposed upon one another; but at one time one nage predominates to the exclusion of the other, and then the other is een alone; and it is only at the moment of change, that the two seem be intermingled. It does not appear to be in the power of the will, rof. Wheatstone remarks, to determine the appearance of either; but, if ne picture be more illuminated than the other, it will be seen during a arger portion of the time.—Many other curious experiments with this imple instrument are related by Prof. Wheatstone; and they all go to onfirm the general conclusion, that the combination of the dissimilar mages furnished by the two eyes is *a mental act*, resulting from an

Fig. 144.




nherent law of our psychical constitution; and that our perceptions of he solidity and projection of objects, near enough to be seen in different perspective with the two eyes, result from this cause. In regard to distant objects, however, the difference in the images formed by the two eyes is so slight, that it cannot aid in the determination; and hence it is, that, whilst we have no difficulty in distinguishing a picture, however well painted, from a solid object, when placed near our eyes (since the idea which might be suggested by the image formed on one eye, will then be corrected by the other), we are very liable to be misled by a delineation, in which the perspective, light and shade, &c., are faithfully depicted, if we are placed at a distance from it, and are prevented from perceiving that it is *but* a picture. In this case, however, a slight movement of the head is sufficient to undeceive us; since by this movement a great change would be occasioned in the perspective view of the object, supposing it to possess an uneven surface; whilst it scarcely affects the image formed by a picture. In the same manner, a person who only possesses one eye, obtains, by a slight motion of his head, the same idea of the form of body, which another would acquire by the simultaneous use of his two eyes.

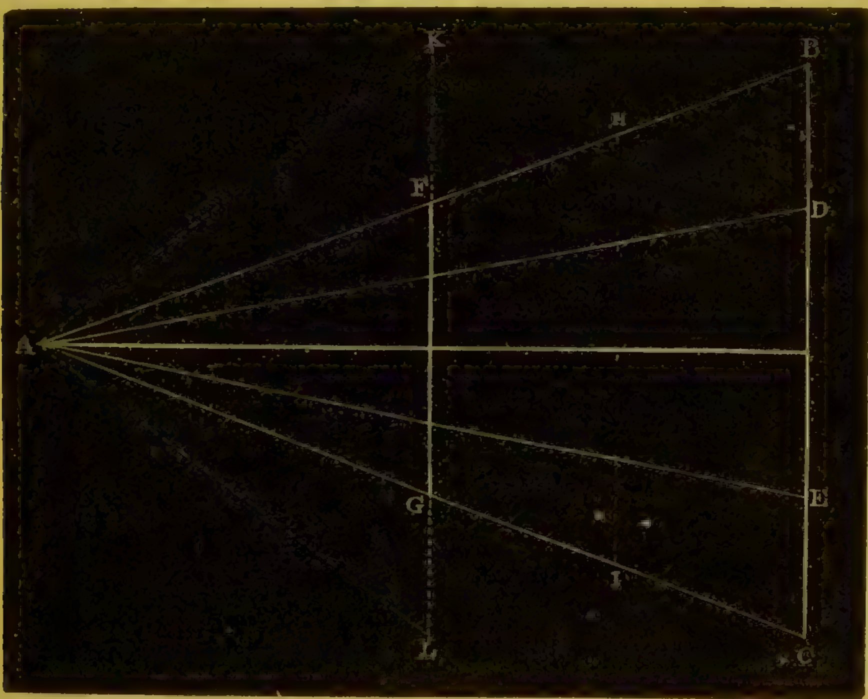
889. The appreciation of the *distance* of objects may be easily shown

to be principally derived from the association, in the Mind, of visual and tactile sensations; assisted, in regard to near objects, by the sensations derived from the muscles of the eye-balls. How much our right estimation of the relative distances of objects not too far removed from the eye depends upon the joint use of *both eyes*, is made evident by the fact, that if we close one eye, we find ourselves unable to execute with certainty many actions (such as threading a needle, or snuffing a candle) which require it guidance; and we can scarcely conceive of any other basis for this appreciation, than that which is afforded by the muscular sensations produced by the different degrees in which the optic axes are made to converge according to the distances of the objects to which we direct our eyes. For in proportion as they are removed further and further, do the optic axes approach parallelism, and the power of appreciating differences of distance is lost; whilst, on the other hand, in proportion as the object is approximated to the eyes, slight differences of distance produce marked differences in the degree of convergence; and these are readily appreciated so as to afford the means of very nice discrimination. The large extent to which our notion of the relative distances of near objects is due to variations in the angle of convergence of the optic axes, is further shown by the following experiment devised by Prof. Wheatstone. If two similar pictures be placed in his mirror-stereoscope, and be made to move to and from the mirrors, so as to vary their distances from these, and therefore from the eyes, without altering the *angle of convergence*, their apparent *sizes* are seen to change (in consequence of the alteration of the *visual angle*), but no positive change is seen in their apparent distances; the effect produced being very much like that of the enlargement or diminution of the images on the screen in the exhibition of the Phantasmagoria, *suggesting* the idea of approach or recession, although we perceive that the distance of the screen from our eyes has undergone no alteration. A converse effect, as we shall presently see (§ 890), is produced by alterations in the angle of convergence, without any real change in the distance of the pictures. This power of estimating distance, however, is obviously, in Man, not an intuitive but an acquired endowment; for it is evident to any observer, that infants, or older persons who have but recently acquired sight, form very imperfect ideas respecting the distance of objects, their attempts to grasp bodies which attract their attention being for a long time unsuccessful; and that they only gradually learn to measure distances by the sight, through the medium of the touch. It is probable, however, that, in the lower Animals, especially such as have early to rely upon their own exertions for the supply of their natural wants, the perception of distance is more intuitive than it is in ourselves; since we may observe them very early performing actions which require an exact appreciation of it.—In regard to *distant* objects our judgment is chiefly founded upon their apparent size, if their actual size be known to us; but, if this be not the case, and if we are so situated that we cannot judge of the intervening space, we principally form our estimate from that effect of different degrees of remoteness upon the distinctness of their colour and outline, which is known to artists as 'aerial perspective.' Hence this estimate is liable to be greatly affected by varying states of the atmosphere, as is particularly known to every one who has visited warmer climates; where the extreme clearness of the air

metimes brings into an apparently near proximity, a hill that rises me miles beyond a neighbouring ridge (the intervening space being dden, so as not to afford any datum for the estimate of the distance of e remote hill), whilst a slight haziness carries its apparent distance to ree or four times the reality.

890. Our estimate of the *size* of an object is partly dependent upon the *sual angle* under which we see it, and partly upon our estimate of its *stance.* The 'visual angle,' formed by imaginary lines drawn from the e (Fig. 145, A) to the extreme points, B, C, of the object, is the measure the size of its image upon the retina; and it is obvious that, if two jects, B C, D E, the former being twice the length of the latter, be placed the same distance, the visual angle B A C being twice as great as the gle D A E, the image of B C upon the retina will be twice as long as that

Fig. 145.




D E, and the mind will estimate their relative sizes accordingly. But if e distance of the object D E from the eye be diminished to one half, that it is brought into the position F G, its visual angle, and consequently the size of its image on the retina, will now be equal to that of C; and the estimate we form of the relative sizes of the two will entirely pend upon the idea we entertain of their relative distances. Hence any rcumstance which modifies that idea, produces a corresponding difference our estimate of their size; so that the apparent size of an object, seen nder the same visual angle, may be estimated as larger or smaller than e reality, according as we suppose it to be more or less distant than it ally is. Of this we have a familiar instance in the fact, that if we meet child whilst we are walking across a common (the flatness of the ground ot giving us much power of estimating the intervening space) in a fog, it ppears to have the stature of a man, and a man seems like a giant; for e indistinctness of outline causes the mind to conceive of the figures as a greater distance than they really are, and their apparent dimensions re augmented in like proportion. For if the object F G (Fig. 145) be

*mentally carried back* to the distance of D E, being still seen under th visual angle F A G (or B A C), it will appear to possess the length B C instea of D E. On the other hand, if the object B C were to be *mentally brough forwards* into the position K L, its apparent size being still determined b its visual angle, it will seem to be reduced to the length F G. This has bee demonstrated by a very ingenious experiment devised by Prof. Wheat stone. For if two similar pictures placed in his mirror-stereoscope, b made so to change their places in regard to the mirrors (by moving in horizontal circle of which the middle point between the mirrors is th centre), that the angle of convergence of the optic axes is increased, whil the actual distance of the pictures from the mirrors, and consequent their visual angles, remain the same, their apparent size is progressive and most remarkably diminished; the mind being accustomed to inte pret increase of the angle of convergence as a proof of diminution of di tance, and being thus impressed by the change as if the pictures ha really advanced to K L; and as they are still seen under the angle B A (or F A G), instead of under the angle K A L, their dimensions are reduce *to the mind's eye* from B C to F G. A very simple and beautiful illustratio of the same principle is furnished by the ordinary stereoscope, when tw pairs of figures (such as those given in Fig. 144) are employed, the effe of one of which is to develope a *projecting*, and that of the other a *recedin* surface. For it will be observed that the relative size of the parts whic appear to project is reduced, whilst that of the apparently-receding par is augmented; as is particularly the case with the square truncated en of the pyramid, which is estimated by most persons as from one-third one-half larger in each of its dimensions in the receding, than it is in th projecting pyramid, notwithstanding that the actual sizes of the squar in the two sets of figures are precisely the same. For supposing H I represent the real side of one of the small squares, which becomes th truncated end of the pyramid; when this is brought forward by the min into the position K L, as the truncated top of a projecting pyramid, bein seen under the visual angle H A I, its apparent size is reduced to F whilst on the other hand, the very same square, carried back by the min to the distance D E, as when it forms the truncated end of the recedin pyramid, is mentally enlarged to the dimensions B C, the visual angle B A being the same as H A I.—It is obvious from what has been stated regard to distance, that our power of forming a true estimate of the rel tive sizes is far greater with regard to *near* objects, whose relati distances we can estimate with tolerable accuracy, than it is with respe to more remote bodies whose relative distances we have no means appreciating; thus, the sun and the moon are of nearly the same appare size to us, though one is about four million times the distance of the othe and we may cover either disc with a sixpence held near the eye, so as be seen under the same visual angle, without the least power of estimati the relative sizes of these objects, save by a calculation based on a kno ledge of their relative distances, because, whilst the one is near, the oth is virtually almost infinitely remote.—The want of innate power in M to form a true conception of either size or distance, is well shown by t effect produced on the mind unprepared for such delusions, by a skilfull painted picture; the view of which is so contrived, that its distance fro the eye cannot be estimated in the ordinary manner; for the objects

presents are invested by the mind with their real sizes and respective istances, as if their real images were formed upon the retina.*

891. From all these considerations, we are led to perceive the truth of e quaint observation made by Dr. Brown,—that "vision is, in fact, the t of seeing things which are invisible;" that is, of acquiring information, means of the eye, which is neither contained in the sensations of sight emselves, nor logically deducible from the intimations which those sentions really convey. We cannot too constantly bear in mind, in treating this subject, that we do not take cognizance by our optic nerves, as we do y the nerves of touch, of material bodies themselves, but of the pictures r images formed by those objects; and whatever be the notions suggested y the picture, *that* can never be transformed into anything else. These otions appear to be, in the lower Animals, entirely of an intuitional or istinctive character; in Man they are so in a much less degree; and though it is impossible to come to a precise conclusion on the subject, om the want of sufficient data, it is indubitable that a large part of the nowledge of the external world, which he derives in the adult condition om the use of his eyes alone, is really dependent upon the early education of his perceptive powers, in which process, the sensations conveyed y different organs are brought into relation with one another.

892. The persistence, during a certain interval, of impressions made pon the retina, gives rise to a number of curious visual phenomena. he prolongation of the impression will be governed, in part, by its preious duration. Thus, when we rapidly move an ignited point through a ircle, the impression itself is momentary, and remains but for a short ime; whilst, if we have been for some time looking at a window, and then lose our eyes, the impression of the dark bars traversing the illuminated pace is preserved for several seconds. Such phenomena can here be only riefly adverted to. One of these is the combination, into a single image, f two or more objects presented to the eye in successive movements; but ese must be of a kind which can be united, otherwise a confused picture produced. Thus in a little toy, called the Thaumatrope, which was ntroduced some years ago, the two objects were painted on the opposite ides of a card,—a bird, for instance, on one, and a cage on the other; nd, when the card was made (by twisting a pair of strings) to revolve bout one of its diameters, in such a manner as to be alternately presenting the two sides to the eye at minute intervals, the two pictures were lended, the bird being seen in the cage. A far more curious illusion, owever, was that first brought into notice by Prof. Faraday; who showed hat, if two toothed wheels, placed one behind the other, be made to evolve with equal velocity, a stationary spectrum will be seen; whilst if ne be made to revolve more rapidly than the other, or the number of eeth be different, the spectrum also will revolve. The same takes place hen a single wheel is made to revolve before a mirror, the wheel and its mage answering the purpose of the two wheels in the former case. On his principle, a number of very ingenious toys have been constructed; in ome of these, the same figure or object is seen in a variety of positions; nd the successive impressions, passing rapidly before the eye, give rise by

* This delusion has been extremely complete, in some of those who have seen the panomic view of London in the Coliseum. A lively and interesting account of it is given in the ournal of the Parsee Shipbuilders, who visited England some time ago.

their combination to the idea, that the object is itself moving throug these positions.*—It is interesting to remark, moreover, that when th eye has been for some time contemplating an object in motion, and is the directed towards stationary objects, *these* appear for a short time to hav a like movement. Any railroad traveller may try this simple experimen by first looking at the hedges, &c. which he is rapidly passing, and the at some part of the interior of the carriage itself, especially one whic presents a series of parallel lines. But when the impression of movemen has been of longer duration, its effects upon the retina are less transient thus, a person who has been for some time on board ship, sees the floor walls, and ceilings of his apartments on shore in a state of continu up-and-down motion, even for some days after he has landed.

893. When the Retina has been exposed for some time to a strong im pression of some particular kind, it seems less susceptible of feeble impressions of the same kind. Thus, if we look at any brightly luminou object, and then turn our eyes on a sheet of white paper, we shall perceiv a dark spot upon it; the portion of the retina, which had been affecte by the bright image, not being able to receive an impression from th fainter rays reflected by the paper. The dark spectrum does not at onc disappear, but assumes different colours in succession,—these being ex pressions of the states through which the retina passes, in its transition t the natural condition. If the eye has received a strong impression fro a coloured object, the spectrum exhibits the *complementary* colour;† thu if the eye be fixed for any length of time upon a bright red spot on white ground, and be then suddenly turned so as to rest upon the whit surface, we see a spectrum of a green colour.—The same explanatio applies to the curious phenomenon of coloured shadows. It may not un frequently be observed at sunset, that, when the light of the sun acquire a bright orange colour from the clouds through which it passes, the sha dows cast by it have a blue tint. Again, in a room with red curtains, th light which passes through these produces green shadows. In both in stances, a strong impression of one colour is made on the general surfa of the retina; and at any particular spots, therefore, at which the ligh is colourless but very faint, that colour is not perceived, its compleme only being visible. The correctness of this explanation is proved by th fact, that, if the shadow be viewed through a tube, in such a manner th the coloured ground is excluded, it seems like an ordinary shadow. It not unlikely that, as Müller suggests, the predominant action of o

* A very beautiful "philosophical toy" was shown to the Author some years since, by inventor, Mr. Roberts, the celebrated machinist of Manchester; consisting in an apparatus which it was made possible to read words printed on a card, although the card itself was ma to revolve on its axis even 30,000 times in a minute. The principle of its construction w simply this,—that the eye caught a succession of glimpses of the card, through a narrow before which a disk with a single corresponding perforation was made to revolve; the rate movement of this disk being so adjusted to that of the card, that whenever the eye caug sight of the latter, it was *momentarily* in the same position, so that, by the succession transient impressions thus made upon the retina, the words printed on the card could distinctly read.

† By the 'complementary' colour is meant that which would be required to make wh or colourless light, when mixed with the original. As red, blue, and yellow are the prim or elementary colours, red is the complement of green (which is composed of yellow a blue); blue is the complement of orange (red and yellow); and yellow of purple (red a blue); and *vice versâ* in all instances.

olour on the retina disturbs (as it were) the equilibrium of its condition, nd excites in it a tendency to the development of a state corresponding that which is produced by the impression of the complementary colour; r the latter is perceived, according to him, even where it does not exist, when the eye, after receiving a strong impression from a coloured spot, d directed upon a completely dark surface or into a dark cavity, still erceives the spectrum. This change, indeed, extends beyond the spot n which the impression is made; for, as is well known to Artists, the ensory impression produced by any colour is greatly affected by neighouring hues. Thus, if four strips of coloured paper, or any other fabric, , B, C, D,—two of them, A, B, of one colour (*e.g.* red), and the other two, , D, of some different colour (*e.g.* blue),—be laid side by side at interals of about half an inch, the hues of the two central strips B, C, will be ecidedly modified by each other's proximity, each approximating to the ue of the complementary colour of the other; so that instead of

| A | B | C | D |
|---|---|---|---|
| red | red | blue | blue. |

we shall see

| A | B | C | D |
|---|---|---|---|
| red | orange red | greenish blue | blue. |

–Upon these properties of the eye are founded the laws of harmonious olouring, which have an obvious analogy with those of musical harmony. ll complementary colours have an agreeable effect, when judiciously isposed in combination; and all bright colours, which are not complementary, have a disagreeable effect, if they are predominant: this is espeially the case in regard to the simple colours, strong combinations of any wo of which, without any colour that is complementary to either of them, re extremely offensive. Painters who are ignorant of these laws, introuce a large quantity of dull grey into their pictures, in order to diminish he glaring effects which they would otherwise produce; but this beneit is obtained by a sacrifice of the vividness and force, which may be ecured in combination with the richest harmony, by a proper attention o physiological principles.

894. Some persons, who can perfectly distinguish *forms*, are deficient, hrough some original peculiarity in the constitution of the retina, in the ower of discriminating *colours*. This is most commonly seen in regard o the complementary colours, especially red and green; such persons not eing able to perceive cherries amidst the leaves on a tree, except by the ifference of their form. Several distinct varieties of this affection may e distinguished, however; these have been classified by Seebeck and Wartmann.*

895. Amongst other curious phenomena of Vision, is the vanishing of mages which fall at the entrance of the optic nerve; as is shown in the ollowing experiment. Let two black spots be made upon a piece of aper, about four or five inches apart; then let the left eye be closed, and he right eye be strongly fixed upon the left-hand spot. If the paper be hen moved backwards and forwards, so as to change its distance from the

* Müller's "Elements of Physiology," (Baly's Translation), p. 1213; and Taylor's Scientific Memoirs," vol. iv. p. 156, et seq.

eye, a point will be found at which the right-hand spot is no longer visible; though it is clearly seen when the paper is brought nearer or removed further. In this position of the eye and object, the rays from the right-hand spot cross to the nasal side of the globe, and fall upon the point of the retina which has just been mentioned. The phenomenon is not confined to that spot, however; nor is it correct to say, as is sometimes done, that the retina is not sensible to light at that point; since, if such were the case, we should see a dark spot in our field of view whenever we use only one eye. The fact is, that a similar phenomenon may occur under somewhat different conditions, in any division of the retina, especially in its lateral parts. Thus, if we fix the eye for some time, until it is fatigued, upon a strip of coloured paper lying upon a white surface, the image of the coloured object will in a short time disappear, and the white surface will be seen in its place; the disappearance of the image, however, is only of a few seconds' duration. The truth seems to be, that there is a tendency in the retina, to the propagation, over neighbouring parts, of impressions which occupy a large proportion of its surface; and that this tendency is the strongest, around the point at which the optic nerve enters, so that the state of this part will generally become similar to that of the surrounding portion of the retina. Hence, when we are using one eye only, we do not perceive any dark spot in the field, but only a certain degree of indistinctness in a portion of the image.

896. Under particular circumstances, we may receive a visual representation of the retina itself; as is shown by the experiment of Purkinje. "If in a room otherwise dark, a lighted candle be moved to and fro, or in a circle, at a distance of six inches before the eyes, we perceive, after a short time, a dark arborescent figure ramifying over the whole field of vision; this appearance is produced by the vasa centralia distributed over the retina, or by the parts of the retina covered by those vessels. There are, properly speaking, two arborescent figures, the trunks of which are not coincident, but on the contrary arise in the right and left divisions of the field, and immediately take opposite directions. One trunk belongs to each eye, but their branches intersect each other in the common field of vision. The explanation of this phenomenon is as follows:—By the movement of the candle to and fro, the light is made to act on the whole extent of the retina, and all the parts of the membrane which are not immediately covered by the vasa centralia are feebly illuminated; those parts, on the contrary, which are covered with those vessels cannot be acted on by the light, and are perceived, therefore, as dark arborescent figures. These figures appear to lie before the eye, and to be suspended in the field of vision."* We have thus another demonstration of the fact that, in ordinary vision, the immediate object of our sensation is a certain condition of the retina, which is excited by the formation of a luminous image.

### 6.—*Sense of Hearing.*

897. In the Ear, as in the Eye, the impressions made upon the sensory nerve are not at once produced by the body which originates the sensation; but they are propagated to it, through a medium capable of transmitting

* Müller's "Elements of Physiology" (Baly's Translation), p. 1163.

them. Here too, therefore, we take cognisance by the mind, not of the sonorous object, but of the condition of the auditory nerve; and all the ideas we form of sounds, as to their nature, intensity, direction, &c., must be based upon the changes which they produce in it. The complex contrivances which we meet with in the organ of Hearing among higher animals, are evidently intended to give them greater power of discriminating sounds, than is possessed by the lower tribes; in which last it is reduced to a form so simple, that it may be questioned whether they can be said to possess an organ of *hearing*, if by this term we imply anything more than the mere consciousness of sonorous vibrations.—There is a considerable difference, however, between the Eye and the Ear, in regard to the special purposes for which they are respectively adapted. In the former we have seen, that the whole object of the instrument is to direct the rays of light received by it, in such a manner, as to occasion them to fall upon the expansion of the optic nerve in similar relative positions, and with corresponding proportional intensities, to those which they possessed when issuing from the object. We have no reason to believe anything of this kind to be the purpose of the Ear; indeed it would be inconsistent with the laws of the propagation of sound. Sonorous vibrations having the most various directions, and the most unequal rates of succession, are transmitted by all media without modification, however numerous their lines of intersection; and wherever these undulations fall upon the auditory nerve, they must cause the sensation of corresponding sounds. Still it is probable that some portions of the complex organ of hearing, in Man and in the higher animals, are more adapted than others to receive impressions of a particular character; and that thus we may be especially informed of the direction of a sound by one part of the organ, of its musical tone by another, and of some other of its qualities by a third.

898. The essential part of an Organ of Hearing is obviously a nerve, endowed with the peculiar property of receiving sonorous undulations, and of transmitting their effects to the Sensorium. This nerve is spread out over the surface of a delicate membrane which lines the Vestibule and its prolongations; and this membrane encloses a fluid, which is the medium whereby the sonorous vibrations received through the external ear are communicated to the nerve. We learn from an examination of the comparative structure of the auditory apparatus in the lower animals, and from the study of its development in the higher, that the part which, being most constantly present and being also the earliest in its development, may be considered as the most essential, is the simple *Vestibular* cavity; which exists where there are no vestiges either of Semicircular Canals, of Cochlea, or of Tympanic apparatus. Such a condition presents itself in some of the higher Invertebrata and in the lowest Fishes; but as we ascend the Vertebrated series, we find the semicircular canals growing out (as it were) of the Vestibule in Fishes, a tympanic apparatus superadded in Reptiles, and a Cochlea first acquiring a more than rudimentary development in the class of Birds, although only presenting in Mammalia that characteristic form from which it derives its name.* Of the mode in which the ultimate subdivisions of the Auditory nerve are distributed

* For a more detailed sketch of the Comparative Anatomy of the Organ of Hearing, see the Author's "Princ. of Physiol., Gen. and Comp.," §§ 822–825.

upon the lining membrane of the labyrinth, it does not yet seem possible to give a certain account; for although Wagner and others have represented them as terminating in free loops, yet more careful observation has rendered this doubtful; and the general analogy between the simpler forms of the auditory and of the visual apparatus, as well as the close correspondence which exists between them in the history of their development (the organ of hearing, like the eye, being budded-off from its sensory ganglion), seem to indicate that the peripheral expansion of the auditory nerve might be expected to have a structure analogous to that of the retina. The most exact observations yet made on this point, seem to be those of the Marquis Corti on the Cochlear nerve.* This nerve passes out from the *modiolus* into a series of anastomosing canals excavated in the osseous *lamina spiralis;* and it there comes into relation with a band of vesicular substance, which lies near the edge of the lamina along its whole length. The component vesicles are elongated, having a central and a peripheral extremity; by the former they are connected with the fibres of the cochlear nerve, the connecting filaments being destitute (as elsewhere) of the double contour, and being very fragile; and by the latter they are similarly connected with the fibres which issue-forth from the osseous lamina, to be distributed upon its membranous continuation. These fibres form fasciculi, which traverse the membranous lamina nearly parallel to each other, and anastomose continually with one another, in such a manner as to present the appearance of looped terminations. According to Corti, however, the fibres really pass-on further, losing their double contour, and becoming gradually incorporated, as it were, with the surrounding tissue.†

899. In order to gain any definite idea of the uses of different parts of the Ear, it is necessary to bear in mind, that sounds may be propagated amongst solid or fluid bodies in three ways; by *reciprocation*, by *resonance*, and by *conduction*.—1. Vibrations of *reciprocation* are excited in a sounding body, when it is capable of yielding a musical tone of definite pitch, and another body of the same pitch is made to sound near it. Thus if two strings of the same length and tension be placed alongside of each other, and one of them be sounded with a violin-bow, the other will be thrown into reciprocal vibration; or if the same tone be produced near the string in any other manner, as by a flute or a tuning-fork, the same effect will result.—2. Vibrations of *resonance* are of somewhat the same character; but they occur when a sounding body is placed in connection with any other, of which one or more parts may be thrown into reciprocal vibration, even though the tone of the whole be different, or it be not capable of producing a definite tone at all. This is the case, for example, when a tuning-fork in vibration is placed upon a sound-board; for even though the whole board have no definite fundamental note,‡ it

* See Kölliker and Siebold's "Zeitschrift für wissenschaftliche Zoologie," 1851, band iii. heft 1.

† Such, also, is the account of their termination given by Messrs. Todd and Bowman, "Physiological Anatomy," vol. ii. p. 81.

‡ The *fundamental note* of a body is the lowest tone which it will yield, when the whole of it is in vibration together. By dividing the body into two or more distinct parts, it may be made to give a great variety of sounds. Thus, if a stretched string be divided by a bridge into two equal parts, each will sound the octave of the fundamental note, or the 8th note above it. If it be divided into three parts, each will give the 12th above the fundamental

will divide itself into a number of parts, which will reciprocate the original sound, so as greatly to increase its intensity; and the same sound-board will act equally well for tuning-forks of several different degrees of pitch. When a smaller body is used for resonance, however, it is essential that there should be a relation between its fundamental note and that of the sonorous body; otherwise no distinct resonance is produced. Thus, if a tuning-fork in vibration be held over a column of air in a tube, of such a length that the same note would be given by its vibration, its sound will be reciprocated. And if it be held over a pipe, the column of air in which is a multiple of this, the column will divide itself into that number of shorter parts, each of which will reciprocate the original sound, and the total action will be one of resonance. But if the length of the pipe bear no such correspondence with the note sounded by the tuning-fork, no resonance is given by the column of air it contains. — 3. Vibrations of *conduction* are the only ones, by which sounds can strictly be said to be propagated. These are distinguishable into various kinds, into which it is not requisite here to inquire. It should be remarked, however, that all media, fluid, liquid, or solid, are capable of transmitting sound in this manner; a vacuum being the only space through which it cannot pass. The transmission is usually much more rapid through solid bodies, than through liquid; and through liquid, than through gaseous. The greatest diminution in the intensity of sound is usually perceived, when a change takes place in the medium through which it is propagated, especially from the aeriform to the liquid.

900. The detailed application of these principles has been most elaborately worked out by Müller; and the following statement of what may be regarded as the present condition of our knowledge of the subject, is little more than an abstract of his results. Considering it desirable, in the first place, to establish the conditions under which those animals hear, that are constantly immersed in water, he made a series of experiments, from which he draws the following conclusions :—I. Sonorous vibrations, excited in water, are imparted with considerable intensity to solid bodies. —II. Sonorous vibrations of solid bodies are communicated with greater intensity to other solid bodies brought in contact with them, than to water; but with much greater intensity to water, than to atmospheric air. —III. Sonorous vibrations are communicated from air to water with great difficulty, this difficulty very much exceeding that with which they are propagated from one part of the air to another; but their transition from air to water is much facilitated, by the intervention of a membrane extended between them. — IV. Sonorous vibrations are not only imparted from water to solid bodies with definite surfaces which are in contact with the water, but are also returned with increased intensity by these bodies to the water; so that the sound is heard loudly in the vicinity of those bodies, in situations where, if it had its origin in the conducting power of the water alone, it would be faint. —V. Sonorous undulations, propagated

note; if into four, the 15th or double octave will be heard; if into five, the 17th; if into six, the 19th; if into seven, the 20½th (flat seventh above the second octave); if into eight, the 22nd or triple octave. A string forcibly set in vibration has a tendency to sound these harmonics with the fundamental note, by spontaneous division into several distinct segments of vibration; as may be easily made evident, by striking one of the lower keys of the piano, and listening to the sounds heard whilst the fundamental note is dying away.

through water, are partially reflected by the surfaces of solid bodies.—vi. Thin membranes conduct sound in water without any loss of its intensity, whether they be tense or lax.—From iii., iv., and vi., we learn the mode in which the sound is conducted to the ear, in aquatic animals not breathing atmospheric air. The labyrinth of such is either entirely inclosed within the bones of the head, as in the Cephalopoda, and in the Cyclostome and Osseous Fishes; or, its cavity being prolonged to the surface of the body, it is there brought into communication with the conducting medium by means of a membrane, besides receiving the vibrations through the medium of the solids of the body, as is the case in Cartilaginous Fishes and Crustacea. It would seem as if, in the Osseous Fishes, the resonance of the cranial bones, in which the labyrinth is imbedded, were sufficient to give the requisite increase of intensity to the sound; whilst in the Cartilaginous orders, the softness of these bones renders some other means necessary. In addition to this, we find in many Fishes a communication with the air-bladder; which indeed seems to have, in these, but little other use. The mode in which this increases by resonance the intensity of the sounds, will appear from the following experimental conclusions.—vii. When sonorous vibrations are communicated from water, to air inclosed in membranes or solid bodies, a considerable increase in the intensity of the sound is produced, by the resonance of the air thus circumscribed.—viii. A body of air inclosed in a membrane, and surrounded by water, also increases the intensity of the sound by resonance, when the sonorous undulations are communicated to it by a solid body.—From these observations it may be concluded, that the air-bladder of Fishes, in addition to other uses, serves the purpose of increasing by resonance the intensity of the sonorous undulations, communicated from the water to the body of the Fish. Moreover, as the conducting and resonant power of the air in the air-bladder is greater in proportion to its density, the influence of this organ on the perception of sounds will, of course, be greater in deep waters, where the pressure upon it is considerably increased.

901. Most animals living in air, are provided with an opening into the Vestibule, covered by a thin membrane; and, in the majority of cases, with a Tympanic apparatus also. The following experimental results bear upon the manner, in which the Ear of such animals is affected by sound.—ix. Sonorous undulations, in passing from air directly into water, suffer a considerable diminution in their strength; while, on the contrary, if a tense membrane exist between the air and the water, the sonorous undulations are communicated from the former to the latter medium with great intensity.—x. The sonorous vibrations are also communicated, without any perceptible loss of intensity, from the air to the water; when, to the membrane forming the medium of communication, there is attached a short solid body, which occupies the greater part of its surface, and is alone in contact with the water.—xi. A small solid body, fixed in an opening by means of a border of membrane, so as to be movable, communicates sonorous vibrations, from air on one side, to water or the fluid of the labyrinth on the other, much better than solid media not so constructed. But the propagation of sound to the fluid is rendered much more perfect, if the solid conductor, thus occupying the opening, is by its other end fixed to the middle of the tense membrane, which has atmospheric air on both

sides.—The fact stated in IX. is evidently one of great importance in the physiology of hearing; and fully explains the nature of the process in those animals, which receive the sonorous vibrations through air, but which have no tympanic apparatus. In X. we have the elucidation of the action of the fenestra ovalis, and of the movable plate of the stapes which occupies it, in animals living in air but destitute of tympanic apparatus; this is naturally the case in many Amphibia; and it may happen as the result of disease in the Human subject. In XI. we have a very interesting demonstration of the purpose and action of the tympanum, in the more perfect forms of the auditory apparatus.—We are now prepared to inquire, in somewhat more of detail, into the actions of the different parts of this apparatus; and it will be better to commence with those of the *Middle* and *Internal Ear*, the accessory organs being afterwards considered.

902. The *Membrana Tympani* consists of three layers; an *external* one continuous with the cutis of the external meatus, and consisting of dermoid tissue with a covering of epidermic cells; an *internal* one, which is extremely thin, continuous in like manner with the mucous membrane lining the tympanic cavity, and also composed of dermoid tissue and epithelium; and a *middle* layer, which, according to the recent researches of Mr. Toynbee,* may be separated into two distinct laminæ, whose fibres run in contrary directions, those of the external layer (which is the stronger of the two) *radiating* from the malleus towards the peripheral ring to which they are attached, whilst those of the internal are *annular*. The fibres of which these laminæ are composed, do not appear to be muscular; nor do they present the longitudinal parallel wavy lines characteristic of ordinary fibrous membranes; and they are rendered opaque by acetic acid. Hence, although those laminæ appear to be derived, the external from the periosteum of the meatus, and the internal from that of the tympanic cavity, they differ from it in elementary structure, and seem to have more in common with the elastic tissue. Mr. Toynbee points out the existence of a tubular ligament, enclosing the tendon of the tensor tympani muscle; and considers that the membrane is maintained by this ligament in a state of moderate tension, the assistance of the muscle being only required to augment this.—The function of the *Membrana Tympani* seems obviously to be the reception of sonorous undulations from the air, in such a manner that it may be thrown by them into a reciprocal vibration, which is communicated to the chain of bones. This membrane, in its usual state, is scarcely on the stretch; and this is found by experiment to be, for a small membrane, the best condition for the propagation of ordinary undulations. This is easily rendered sensible in one's own person; for an increased tension may be given to the membrana tympani, either by holding the breath and forcing air into the Eustachian tube, so as to distend it from within, or by exhausting the cavity, so as to cause the external air to make increased pressure upon it; and in either case, the hearing is found immediately to become indistinct. It is observed, however, that grave and acute sounds are not equally affected by this action; for the experimenter renders himself deaf to grave sounds, whilst acute sounds are heard even more distinctly than before. This fact is easily understood by referring to the laws of Acoustics already mentioned. The

* "Philosophical Transactions," 1851.

greater the tension to which the membrana tympani is subjected, the more acute will be its fundamental tone: and as no proper reciprocation can take place in it, to any sound *lower* than its fundamental tone, its power of repeating perfectly the vibrations proper to the deeper notes will diminish. The nearer a sound approaches to the fundamental note proper to the tense membrane, the more distinctly will it be heard. On the other hand, when the membrane is in its natural relaxed condition, its fundamental note is very low, and it is capable of repeating a much greater variety of sounds; for, when it receives undulations of a higher tone than those to which the whole membrane would reciprocate, it divides itself into distinct segments of vibration, which are separated by lines of rest; and every one of these reciprocates the sound,* at the same time rendering it more intense by multiplication. These facts enable us to understand the influence of the tensor tympani muscle, in modifying the tension of the membrane, and thus causing it to vibrate in reciprocation to sounds having a great variety of fundamental notes. Moreover, the fact that some persons are deaf to grave sounds, whilst they readily hear the more acute, is thus accounted for. The tensor tympani, like the iris, is probably excited to operation by a reflex action; and it is by no means improbable that one of its functions may be, to prevent the internal ear from being too violently affected by loud sounds, by putting the membrana tympani into such a state of tension as not readily to reciprocate them.

903. The uses of the *Tympanic Cavity* are very obvious. One of its purposes is to render the vibrations of the membrane quite free; and the other, to isolate the chain of bones, in such a manner as to prevent their vibrations from being weakened by diffusion through the surrounding solid parts. As to the objects of the Eustachian tube, however, opinions have been much divided. From the experiments of Müller it appears that it does not increase the intensity of sound, but that it prevents a certain degree of dulness which would attend it if the cavity of the tympanum were completely closed; of this dulness we are conscious, when any tumefaction of the fauces causes an occlusion of the extremity of the tube. It has been supposed that, among other uses, this canal serves for the conduction of the speaker's voice to his ears; but this is certainly not the case in any considerable degree; for, when the Eustachian tubes are obstructed by disease, the patient hears his own voice well, though other sounds are indistinct; and it is easily shown, that its transmission is chiefly accomplished in other ways. The common idea is, that it serves the same purpose with the hole in an ordinary drum; the effect of which is generally supposed to be, the removal of an impediment to the vibrations of the membrane, that would be offered by the complete inclosure of the air within. It does not appear, however, that any such impediment is really offered; and the effect of the hole in the drum seems rather to be the communication, to the ear of the auditor, of the sonorous

* This is very easily proved by experiment on a membrane stretched over a resonant cavity; for if light sand be strewed upon it, and a strong musical tone be produced in its vicinity, the membrane will immediately be set in vibration, not as a whole (unless its fundamental note be in unison with that sounded), but in distinct segments, of which every one reciprocates the sound; from the vibrating parts, the sand will be violently thrown off; but it will settle on the intermediate lines of rest, forming a variety of curious figures, which are known as the *nodal* lines.

vibrations of the contained air; which are thus transmitted directly through the atmosphere, instead of being weakened by transmission through the walls of the instrument. Hence there is no real analogy in the two cases. The principal object of the Eustachian tube (which is always found where there is a tympanic cavity) seems to be, the maintenance of the equilibrium between the air within the tympanum and the external air; so as to prevent inordinate tension of the membrana tympani, which would be produced by too great or too little pressure on either side, and the effect of which would be imperfection of hearing. It also has the office of conveying away mucus secreted in the cavity of the tympanum, by means of the vibratile cilia which clothe its lining membrane; and the deafness, consequent on occlusion of this tube, is in part explicable by the accumulation which will then take place in the cavity.

904. From what has been stated, it is evident that sonorous undulations taking place in the air, will be propagated to the fluid contained in the labyrinth, — through the tympanum, the chain of bones, and the membrane of the *fenestra ovalis* to which the stapes is attached,—without any loss, but rather an increase, of intensity. Why water should be chosen as the medium through which the impression is to be made upon the nerve, it is impossible for us to say with anything like certainty, in our present state of ignorance as to the physical character of that impression. But the problem being, to communicate to water the sonorous undulations of air, the experimental results already detailed satisfactorily prove that — whilst this may be accomplished, in a degree sufficient for the wants of the inferior animals, by the simple interposition of a tense membrane between the air and the fluid, — the tympanic apparatus of the higher classes is most admirably adapted for this purpose. The fenestra ovalis is not, however, the only channel of communication between the tympanum and the labyrinth; for there is, in most animals, a second aperture, the *fenestra rotunda,* leading into the cochlea, and simply covered with a membrane. It is generally supposed that, the labyrinth being filled with a nearly incompressible fluid, this second aperture is necessary to allow the free vibration of that fluid; the membrane of the fenestra rotunda being made to bulge out, as that of the fenestra ovalis is pushed in. It may, however, be easily shown by experiment, as well as by reference to comparative anatomy, that no such contrivance is necessary; for sonorous undulations may be excited in a non-elastic fluid, completely inclosed within solid walls at every part, except where these are replaced by the membrane through which the vibrations are propagated; and this is precisely the condition, not only of the Invertebrated animals, but even of Frogs; in which last a tympanic apparatus exists, without a second orifice into the labyrinth. Moreover it is certain, that the vibrations of the air in the cavity of the tympanum, must of themselves act upon the membrane of the fenestra rotunda; and this is perhaps the most direct manner in which the fluid in the cochlea will be affected, although it will ultimately be thrown into much more powerful action, by the transmission of vibrations from the vestibule. For it has been satisfactorily determined by experiment (XII), that vibrations are transmitted with very much greater intensity to water, when a tense membrane, and a chain of insulated solid bodies capable of free movement, are successively the conducting media, than when the media of

communication between the vibrating air and the water are the same tense membrane, air, and a second membrane : — or, to apply this fact to the organ of hearing, the same vibrations of the air act upon the fluid of the labyrinth with much greater intensity, through the medium of the chain of auditory bones and the fenestra ovalis, than through the medium of the air of the tympanum and the membrane closing the fenestra rotunda. — The fenestra rotunda is not to be considered as having any peculiar relation with the cochlea; since, in the Turtle tribe, the former exists without the latter.

905. It is obviously in the *Labyrinth*, as a whole, that the sonorous vibrations are brought to bear upon the Auditory nerve spread out to receive them. In regard to the special functions of particular parts of the labyrinth, however, no certainty can be said to exist. The membrane which lines its cavities not only contains a liquid (the *endo-lymph*), but is also separated from the osseous wall by another collection of liquid, the *peri-lymph;* so that it is suspended, as it were, in a liquid which bathes both its surfaces. In the cavity of the *Vestibule*, which is subdivided by a membranous partition into two, are found small masses of concretionary particles, collectively named *otoconia* or ear-powder; these are obviously the rudiments of the *otoliths*, or ear-stones, whose presence, in animals with a less perfect auditory apparatus, seems needful to intensify the undulations.—It is commonly supposed that the *Semicircular Canals* have for their peculiar function, to receive the impressions by which we distinguish the *direction* of sounds; and it is certainly a powerful argument in support of this view, that, in almost every instance in which these parts exist at all, they hold the same relative position to each other as in Man, their three planes being nearly at right angles to one another. The idea, however, must be regarded as a mere speculation, the value of which cannot be decided without an increased knowledge of the laws according to which sonorous vibrations are transmitted.—Regarding the special function of the *Cochlea*, there is precisely the same uncertainty. This part of the organ is peculiar in one respect, that the expansion of the auditory nerve is here spread out (within the lamina spiralis) in closer proximity with the bone itself, than it is in any other part of the labyrinth; and moreover the peri-lymph is here deficient, so that the membranous lining of the cochlea is in absolute contact with its osseous wall. It is not easy to see, however, what can be the peculiar object of this disposition, in regard to the function of hearing. It has been surmised by M. Dugès, that by the cochlea we are especially enabled to estimate the *pitch* of sounds, particularly of the voice; and he adduces, in support of this idea, the fact, that the development of the cochlea follows a very similar proportion with the compass of the voice. This is much the greatest in the Mammalia; less in Birds; and in Reptiles, which have little true vocal power, the cochlea is reduced to its lowest form, disappearing entirely in the Amphibia. That there should be an acoustic relation between the voice and ear of each species of animal, cannot be regarded as improbable; but the speculation of M. Dugès can at present only be received as a stimulus to further inquiry.

906. We have now to consider the functions of the accessory parts,— the *External Ear*, and the *Meatus*. The Cartilage of the external ear may propagate sonorous vibrations in two ways; by reflection, and by

conduction. In reflection, the concha is the most important part, since it directs the reflected undulations towards the tragus, whence they are thrown into the auditory passage. The other inequalities of the external ear cannot promote hearing by reflection; and the purpose of the extension of its cartilage is evidently to receive the sonorous vibrations from the air, and to conduct them to its point of attachment. In this point of view, the inequalities become of importance; for those elevations and depressions upon which the undulations fall perpendicularly, will be affected by them in the most intense degree; and in consequence of the varied form and position of these inequalities, sonorous undulations, in whatever direction they may come, must fall advantageously upon some of them.—The functions of the Meatus appear to be threefold. The sonorous undulations entering from the atmosphere are propagated directly, without dispersion, to the membrana tympani:—the sonorous undulations received on the external ear, are conveyed along the walls of the meatus to the membrana tympani:—the air which it contains, like all insulated masses of air, increases the intensity of sounds by resonance. That, in ordinary hearing, the direct transmission of atmospheric vibrations to the membrana tympani, is the principal means of exciting the reciprocal vibrations of the latter, is sufficiently evident; the undulations which directly enter the passage, will pass straight on to the membrane; while those that enter obliquely will be reflected from side to side, and at last will fall obliquely on the membrane, thus perhaps contributing to the notion of direction. The power of the lining of the meatus to conduct sound from the external ear, is made evident by the fact, that, when both ears are closely stopped, the sound of a pipe having its lower extremity covered by a membrane, is heard more distinctly when it is applied to the cartilage of the external ear itself, than when it is placed in contact with the surface of the head. The resonant action of the air in the tube is easily demonstrated, by lengthening the passage by the introduction of another tube; the intensity of external sounds, and also that of the individual's own voice, as heard by himself, is then much increased.

907. Many facts prove, however, that the fluid of the Labyrinth may be thrown into vibration in other ways than by the Tympanic apparatus. Thus in Osseous Fishes, it is only by the vibrations transmitted through the bones of the head, that hearing can take place. There are many persons, again, who can distinctly hear sounds which are thus transmitted to them; although, through some imperfection of the tympanic apparatus, they are almost insensible to those which they receive in the ordinary way. It is evident, where this is the case, that the nerve must be in a state fully capable of functional activity; and, on the other hand, where sounds cannot thus be perceived, there will be good reason to believe that the nerve is diseased.

908. A single impulse communicated to the Auditory nerve, in any of the foregoing modes, seems to be sufficient to excite the momentary sensation of *sound;* but most frequently a series of such impulses is concerned, there being but few sounds which do not partake, in a greater or less degree, of the character of a *tone.* Any continuous sound or tone is dependent upon a succession of impulses; and its acuteness or depth is governed by the rapidity with which these succeed one another. It is

not difficult to ascertain by experiment, what number of such impulses or undulations are required, to give every tone which the ear can appreciate. Thus, if a circular plate, with a number of apertures at regular intervals, be made to revolve over the top of a pipe through which air is propelled, a succession of short *puffs* will be allowed to issue from this; and, if the revolution be sufficiently rapid, these impulses will unite into a definite tone. In the same manner, if a spring be fixed near the edge of a revolving toothed wheel, in such a manner as to be caught by every tooth as it passes, a succession of *clicks* will be heard; and these too, if the revolution of the wheel be sufficiently rapid, will produce a tone. The number of apertures in the plate which pass the orifice of the pipe in a given time, or the number of teeth which pass the spring, being known, it is easy to see that this must be the number of impulses required to produce the given tone. Each impulse produces a double vibration,—forwards and backwards (as seen when a string is put in vibration, by pulling it out of the straight line); hence the number of impulses is always half that of the single vibrations. The maximum and minimum of the intervals of successive pulses, still appreciable by the ear as determinate sounds, have also been determined by M. Savart, more satisfactorily and more accurately than had previously been done. If their intensity be great, sounds are still audible which result from the succession of 24,000 impulses in a second; and this, probably, is not the extreme limit to the acuteness of sounds perceptible by the ear. From some observations of Dr. Wollaston's, it seems probable that the ears of different individuals are differently constituted in this respect,—some not being able to hear very acute tones produced by Insects, or even Birds, which are distinctly audible to others. Again, the sound resulting from 16 impulses per second, is not, as has been usually supposed, the lowest appreciable note; on the contrary, M. Savart has succeeded in rendering tones distinguishable, which are produced by only 7 or 8 impulses in a second; and continuous sounds of a still deeper tone could be heard, if the individual pulses were sufficiently prolonged. In regard, however, to the precise time during which a sonorous impression remains upon the ear, it is difficult to procure exact information, since it departs more gradually than do visual impressions from the eye. This is certain, however,—that it is much longer than the interval between the successive pulses in the production of tones; since it was found by M. Savart, that one or even several teeth might be removed from the toothed wheel, without a perceptible break in its sound,—showing that, when the tone was once established, the impression of it remained during an intermission of some length.

909. The Ear, like the Eye, may vary considerably as regards general acuteness, amongst different individuals; and its power may be much increased by practice. A part of this increase depends, however, as in other instances, upon the greater attention which its fainter indications receive; but a part, also, upon an increased use of the organ. The power of hearing very faint sounds is as different from the power of distinguishing musical tones, as the power of discerning very minute objects, or of seeing with very faint degrees of light, is from that of distinguishing colours. Many persons are altogether destitute of what is termed a *musical ear;* whilst others are endowed with it in a degree which is a source of great

discomfort to them, since every discordant sound is a positive torment. The power of distinguishing the *direction* of sounds appears to be, in Man at least, for the most part acquired by habit. It is some time before the infant seems to know anything of the direction of noises which attract his attention. Now although there can be no question, that this perception is acquired by attention to certain variations in the impressions made upon the nerve, through the medium either of the tympanic apparatus, or of the bones of the head, yet it is equally evident, that there can be nothing in these variations themselves adequate to excite the idea, and that it must therefore be either intuitive or acquired by habit. This is a consideration of some importance, in regard to the similar question as to the sense of Visual direction. In some cases we are probably assisted by the relative intensity of the sensations, communicated by the two ears respectively. The idea of the *distance* of the sonorous body is another acquired perception, depending principally upon the loudness or faintness of the sound, when we have no other indications to guide us. In this respect there is a great similarity between the perception of the distance of an object, through the Eye by its size, and through the Ear by the intensity of its sound. When we know the size of the object, or are acquainted with the usual intensity of its sound, we can judge of its distance; and *vice versâ*, when we know its distance, we can at once form an idea of its real from its apparent size, and of its real strength of tone from that which affects our ears. In this manner, the mind may be affected with corresponding deceptions through both senses; thus, in the Phantasmagoria, the figure being gradually diminished whilst its distance remains the same, it appears to the spectators to recede, the illusion being more complete if its brightness be at the same time diminished; and the effect of a distant full military band gradually approaching, may be alike given by a corresponding *crescendo* of concealed instruments. It is upon the complete imitation of the conditions which govern our ideas of the intensity and direction, as well as of the character, of sounds, that the deceptions of the Ventriloquist are founded.

910. Some facts of much interest have lately been ascertained, in regard to an occasional variation in the rapidity of the perception of sensory impressions, received through the Eye and through the Ear. These facts are the result of comparisons made amongst different astronomical observers, who may be watching the same visual phenomenon, and *timing* their observations by the same clock; for it has been remarked, that some persons see the same occurrence, a third or even a half of a second earlier than others. There is no reason to suppose from this, however, that there is any difference in the rate of transmission of the sensory impressions in the two nerves. The fact seems rather to be, that the Sensorium does not readily perceive two different impressions with equal distinctness; and that, when several impressions are made on the senses at the same time, the mind takes cognizance of one only, or perceives them in succession. When, therefore, both sight and hearing are directed simultaneously to two objects, the communication of the impression through one sense will necessarily precede that made by the other. The interval between the two sensations is greater in some persons than in others; for some can receive and be conscious of many impressions, seemingly at the same moment; whilst in others a perceptible space must elapse.

911. Amongst other important offices of the power of Hearing, is that of supplying the sensations by which the Voice is regulated. It is well known that those, who are born entirely deaf, are also dumb; that is, they do not spontaneously or imitatively form articulate sounds, though not the least defect exist in their organs of voice. Hence it appears that the vocal muscles are usually guided in their action by the sensations received through the Ears, in the same manner as other muscles are guided by the sensations received through themselves; but when the former are deficient, the action of the vocal muscles may be guided by the latter (§ 751).

# CHAPTER XVI.

## OF MUSCULAR MOVEMENTS.

### 1. *General Considerations.*

912. By far the larger proportion of the Muscular apparatus of the Human Body, may be considered in the light of an instrument whereby the Nervous System is enabled to give motion to its parts, and thus to effect those changes in its relation to the external world, which are requisite for its physical well-being, or which are the expressions of its psychical powers. There is probably no part of the Muscular System which is altogether beyond the pale of Nervous agency; but a tolerably definite line of demarcation may be drawn, both structurally and functionally, between the two primary subdivisions of this system: in the first of which —the Muscular Apparatus of Organic Life—the actions are but little dependent upon nervous agency; whilst in the second—the Muscular Apparatus of Animal Life—scarcely any action takes place but what is called-forth by nerve-force. The *First* group consists of the muscular envelopes which surround the various open cavities of the body, and which form part of its general investment; its office being to aid in the performance of the Organic functions, by giving motion to the contents of the cavities, or by maintaining a proper state of tension around them; and it is composed almost entirely of the *non-striated* or smooth form of muscular fibre, the only marked exception being in the case of the heart. Under this category rank the proper muscular coat of the alimentary canal, from its commencement in the œsophagus to its termination at the anus; the muscular coats of the gland-ducts which discharge themselves into this; the muscular fibres of the trachea and bronchial tubes; the muscular substance of the heart, and the muscular coats of the blood-vessels and absorbents generally; the muscular walls of the ureters, bladder, urethra, and vasa deferentia in the male, and of the ureters, bladder, urethra, fallopian tubes, uterus, and vagina of the female; and finally, the muscular substance of the skin. With regard to nearly all these parts, as already pointed out, it is difficult to obtain evidence that nervous agency has anything to do with their contractions; and all the evidence yet adduced tends only to show, that contractions *may be* excited through the nervous system, *not* that they *habitually are so;* their ordinary contractions being produced either by their own motility (§ 499), or by stimuli directly applied to themselves.—The *Second* of the above-named

divisions consists of all those muscles which are usually styled voluntary, since they can be put or retained in action by the mandates of the Will; but besides these, it includes a large group of muscles (those, namely, that are concerned in the functions of Deglutition, Respiration, Vomiting, Defecation, and Urination), over which the Will exerts only a partial control, their activity being usually called forth automatically. It would seem as if this group were placed under the same conditions, as regards their dependence on Nervous agency, with those more properly termed voluntary, in order that the Will, which is altogether powerless over the Muscular Apparatus of Organic Life, may bring their operations into harmony with the general requirements of the system; the functions in question begin those which constitute (so to speak) the meeting-points between the Organic and Animal life. For as we descend the scale of animal life, we find that they lose more and more of the character they possess in Man, becoming more and more exclusively automatic, and at last being even transferred from the more elaborate mechanism of muscular contraction, to the simple operation of ciliary vibration.* Nearly all those muscles in the Human body, which are ordinarily called into action by the Cranio-Spinal nerves, are composed of *striated* fibre; the most remarkable exception being the muscular structure of the Iris. And it is peculiarly characteristic of them, that whilst forcible and united contractions of all the fasciculi at once are called-forth by irritating their nerves, the effect of direct stimulation is limited to the fasciculus irritated.

913. It is obvious from what has preceded, that the system of classifying the Muscles under the categories of *voluntary* and *involuntary*, cannot be consistently maintained. It is quite true that all the Muscles of Organic Life may be truly styled 'involuntary;' for although they are capable of being influenced by emotional and ideational states of mind (§ 923), yet the Will cannot exert any direct influence upon them, only affecting them indirectly by its power of determining these states. But over those Muscles, also ministering to the Organic functions, and doing so in obedience to impulses purely automatic, which are called into action by the Cranio-Spinal nerves, the Will, as we have seen, exerts some power; and such, therefore, cannot be properly regarded as involuntary, since the Will can influence their actions; whilst they are far from being truly voluntary, since the Will cannot control their tendency to automatic action beyond a certain limited amount. On the other hand, every one of the Muscles usually styled voluntary, because ordinarily called into action by the Will, is liable to be thrown into action involuntarily; either by an Excito-motor stimulus, as in tetanic convulsions, or by Consensual action, as in tickling, or Emotionally, as in laughter or rage, or simply Ideationally, as in somnambulism and analogous states. Hence although there are certain groups of muscles which are more frequently acted-on by the Will than by any other impulse, and certain others which are more frequently played-on by the Emotions, and so on, it becomes obvious that every muscle called into contraction by the Cranio-Spinal nervous system, is capable of receiving its stimulus to movement from *any* of these

* Thus in the Oyster and other Bivalve Mollusks, which have a complicated digestive, circulating, and respiratory apparatus, mouth is brought to the food, fæcal matters are expelled from the anus, and a constant current of water is made to sweep over the respiratory surface, entirely by ciliary motion.

sources; the nerve-force transmitted along the motor-fibres, being issued either from the Spinal Cord, from the Sensory Ganglia, or from the Cerebrum, as the case may be, but being in its nature and effects the same in every instance.

914. The grouping or combination of Muscular actions, which takes place in almost every movement of one part of the body upon another, must be attributed, not to any peculiar sympathy among the Muscles themselves, but to the mode in which they are acted-on by the Nervous Centres. This is most obviously the case with regard to those of the primarily-automatic class; but it cannot be in the least degree doubtful, as to those of the secondarily-automatic kind (such as walking), which, though at first directed by the Will, come by habit to be performed under conditions essentially the same with the preceding; and when it is borne in mind that even in voluntary movements the Will cannot single-out any one muscle from the group with which it usually co-operates, so as to throw this into separate contraction, but is limited to determining the result (§ 758), it seems pretty obvious that even here the grouping is effected by the endowments of the Automatic centres from which all the motor impulses immediately proceed to the muscles, and not by Cerebral agency. In fact, the whole process by which we acquire the power of adapting our muscular actions to the performance of some new kind of movement,—as in the case of an infant learning to walk, a child learning to write, an artizan learning some occupation which requires nice manipulation, a musical performer learning a new instrument, and so on,—is found, when attentively studied, to indicate that the Will is far from having that direct and immediate control over the contractions of the Muscles, which it is commonly reputed to possess; and that the operation really consists in the gradual establishment of a new grouping of the separate actions, in virtue of which, the stimulus of a Volitional determination, acting under the guidance of the muscular sensations, henceforth calls into contraction the group of muscles whose agency is competent to carry that determination into effect. For however amenable any set of muscles (as those of the arm and hand) may have become to the direction of the Will, in any operations which they have been previously accustomed to perform, it is only after considerable practice that they can be trained to any method of combined action which is entirely new to them; and even if we attempt to bring our anatomical knowledge into use for such a purpose, by mentally fixing upon certain muscles whose action we wish to intensify and to associate with those of others, we find that such a method of proceeding affords no assistance whatever, but rather tends to impede our progress, by drawing-off the attention from the 'guiding sensations' (visual, muscular, &c.), which are the only regulators that can be depended upon for determining the due performance of the volitional mandate.—Hence we are led by these considerations, as by those stated in the preceding paragraph, to the conclusion, that the agency which directly affects the muscles is of the same kind, and that it operates under the same instrumental conditions, whatever be the primal source of the motor power. And in watching the gradual acquirement of the capacity for different kinds of movement, during the periods of Infancy and Childhood in the Human subject, we find everything to confirm this conclusion. For it becomes obvious that the acquirement of Voluntary power over the

movements of the limbs is just as gradual as it is over the direction of the thoughts (§ 839); all the activity of the body, as well as of the mind, being in the first instance automatic, and the Will progressively extending its domination over the former, as over the latter, until it brings under its control all those muscular movements which are not immediately required for the conservation of the body, and turns them to its own uses.*

## 2. *Of the Symmetry and Harmony of Muscular Movements.*

915. It might have been not unreasonably supposed, *à priori*, that those muscles would have been most readily put into simultaneous contraction, which correspond to each other on the two sides of the body; in other words, that *symmetrical* movements would be those most readily performed. Such, however, is by no means the case; for in many of our most familiar actions, we consentaneously exert different muscles on the two sides of the body. Thus, in ordinary walking, we advance one leg whilst we push backwards (so as to urge the body forwards) with the other; and in the swinging of the arms which is in most persons a natural part of this mode of locomotion, the arms of the two sides move forwards and backwards alternately, and the arm of either side is advanced, not with the leg of its own side, but with that of the opposite side,—any other combination being felt as unnatural, and being only performed by a conscious effort. Now it is plain that this grouping of the muscular movements arises out of its *felt* conformity to the end in view, and that it is regulated by the guiding sensations which indicate to us the progression and balance of the body. The infant, in learning to walk, is prompted by an instinctive tendency to put one foot before the other, as may be noticed at a very early period, when it is first held so as to feel the ground with its feet; and in attempting to balance itself when first left to stand alone, it moves its arms with a like intuitive impulse, not based upon experience. All that experience does, in either case, is to give that precise adjustment to the muscular action, which makes it perfectly conformable to the indications afforded by the muscular sensations. Thus, if we advance each arm with its corresponding leg, we feel that the balance of the body is not nearly as readily maintained, as it is when we advance the arm with the leg of the opposite side; and thus, without any design or voluntary determination on our own parts, the former comes to be our settled habit of action. This kind of adjustment, in the case

* The aptitude which is acquired by practice, for the performance of certain actions that were at first accomplished with difficulty, seems to result as much from a change which the continual repetition of them occasions in the Muscle, as in the habit which the Nervous system acquires of exciting their performance. Thus almost every person learning to play on a musical instrument, finds a difficulty in causing the two shorter fingers to move independently of each other and of the rest; this is particularly the case in regard to the ring-finger. Any one may satisfy himself of the difficulty, by laying the palm of the hand flat on a table, and raising one finger after the other, when it will be found, that the ring-finger can scarcely be lifted without disturbing the rest,—evidently from the difficulty of detaching the action of that portion of the *extensor communis digitorum*, by which the movement is produced, from that of the remainder of the muscle. Yet to the practised musician, the command of the Will over all the fingers becomes nearly alike; and it can scarcely be doubted that some change in the structure of the muscle, or a new development of its nerve-fibres, takes place, which favours the isolated operation of its several divisions.

before us, is by no means limited to the muscles of the limbs; for there is scarcely any muscle of the trunk or head that is not exerted with some degree of consentaneous energy, however unconsciously to ourselves, in the act of walking. The difficulty which would attend the voluntary harmonization of all these separate actions, is remarkably evinced by the fact, that no mechanist, however ingenious, has ever succeeded in constructing an automaton that should *walk* like Man; the alternate shifting of the centre of gravity from one side to the other, upon so small a base as the human foot affords, simultaneously with its movement in advance, constituting the great difficulty of biped progression. But all this adjustment is affected in our own organisms, *for* us, rather than *by* us; the act of harmonization, when once fully mastered, being attended with no effort to ourselves, but the whole series of complex movements being performed in obedience to the simple determination *to walk*, under the automatic guidance of the senses, which instantly reveal to us any imperfection in the performance.—The same view extends itself readily to other combinations of dissimilar and non-symmetrical movements, which are less *natural* to Man, but which may be readily acquired *artificially* if they all harmonize in a common purpose, and are under the guidance of the same set of sensations. Thus, the performer on the organ uses his two hands to execute different movements (in very different positions, it may be) on the 'manual' keys, one of his feet may be on the 'swell' pedal, and the other may be engaged in playing on the 'pedal' keys; but all these diverse actions are harmonized by their relation to the same set of auditory sensations; and if the result be not that which the performer anticipated, an immediate correction is made.

916. It would be easy to multiply instances of the same kind, all illustrative of the general principle, that the facility with which we voluntarily combine different movements is chiefly determined, not by their *symmetrical* character, but by their *conformableness to a common end*, and by the *harmony of their guiding sensations* with reference to that end;* but it will be desirable to dwell particularly on the *Movements of the Eye*, as presenting certain points of peculiar interest, some of which have an important bearing on Surgical practice.—It will be recollected that, in the Human Orbit, six muscles for the movements of the eyeball are found; the four Recti, and the two Oblique muscles. The precise actions of these are not easily established by experiment on the lower animals; for in all those which ordinarily maintain the horizontal position, there is an additional muscle, termed the *retractor*, which embraces the whole posterior portion of the globe, and passes backwards to be attached to the bottom of the

* Two simple examples, however, may be cited, of the difficulty which attends the simultaneous performance of movements that are not harmonious. If we attempt to elevate one eyelid whilst we are depressing the other, we find that a considerable effort is required to accomplish the action, although the elevation or depression of both eyelids together is performed with so little effort that we are scarcely conscious of it; and the difficulty is increased if we half-shut both eyes, and then try to close one and to open the other. So if we try to move our two hands, as if they were simultaneously winding cord *in opposite directions* upon two reels placed in front of us, we shall find ourselves unable to do so without a constant exercise of the attention, and even then but slowly and with difficulty; although the very same movements may be separately performed, or a movement of both hands in the same direction, with the greatest facility.

orbit.* If the origin and insertion of the four *Recti* muscles be examined, however, no doubt can remain that each of them, acting singly, is capable of causing the globe to revolve in its own direction,—the superior rectus causing the pupil to turn upwards,—the internal rectus causing it to roll towards the nose,—and so on. A very easy and direct application of the laws of mechanics will further make it evident to us, that the combined action of any two of the Recti muscles must cause the pupil to turn in a direction intermediate between the lines of their single action; and that *any* intermediate position may thus be given to the eyeball by these muscles alone. This fact, which has not received the attention it deserves, leads us to perceive that the Oblique muscles must have some supplementary function. It may be objected that this is a theoretical statement only; and that there may be some practical obstacle to the performance of diagonal movements by the Recti muscles, which renders the assistance of the Obliques essential for this purpose. But to this it may be replied, that *no single* muscle can direct the ball either downwards and inwards, or upwards and outwards; and that, as we have good reason to believe *these* movements to be effected by the combination of the Recti muscles, there is no reason why the other diagonal movements should not also be due to them.—The most probable account of the functions of the *Oblique* muscles of the eye, seems to be that, which was long ago suggested by John Hunter, and which has received confirmation from the experiments of Dr. G. Johnson.† It has been just shown that the action of the Recti muscles upon the pupil, is such as to cause it to *revolve* in any given direction; and this is put in force, not merely to alter the range of vision, the head remaining stationary; but also to keep the range of vision the same, and to cause the images of the objects upon which our gaze is fixed, still to fall upon the same parts of the retinæ, by maintaining the position of the eyes when the head is moved upwards, downwards, from side to side, or in any intermediate direction. But these muscles are not able to *rotate* the eyeball upon its antero-posterior axis; and such rotation is manifestly necessary to preserve the fixed position of the eyeball, and consequently to keep the image of the object under survey upon the same part of the retina, when the head is inclined sideways, or bowed towards one shoulder and then towards the other. It appears from the experiments of Dr. G. Johnson, that the action of the Oblique muscles is exactly adapted to produce such a rotation; the Inferior oblique, in its contraction, causing the eyeball to move upon its antero-posterior axis, in such a manner that a piece of paper, placed at the outer margin of the cornea, passes downwards

* This muscle is most developed in Ruminating animals, which, during their whole time of feeding, carry their heads in a dependent position. In most Carnivorous animals, instead of the complete hollow muscular cone (the base inclosing the eyeball, whilst the apex surrounds the optic nerve,) which we find in the Ruminants, there are four distinct strips, almost resembling a second set of recti muscles, but deep-seated, and inserted into the posterior instead of the anterior portion of the globe. It is obvious that the actions of these must greatly affect the results of any operations which we may perform upon the other muscles of the Orbit; and, as it is impossible to divide the former, without completely separating the eye from its attachments, we have no means of correcting such results, but by reasoning alone. Experiments upon animals of the order Quadrumana, most nearly allied to Man, would be more satisfactory; as in them, the retractor muscle is almost or entirely absent.

† "Cyclopædia of Anatomy and Physiology," vol. iii. p. 790.

and then inwards towards the nose; and the Superior oblique effecting precisely the reverse action, the paper at the outer margin of the cornea passing first upwards and then inwards. There was not the slightest appearance, in these experiments, of elevation, depression, abduction, or adduction, of the cornea, as a result of the action of the Oblique muscles; all these movements being attributable to the Recti alone.*

917. On studying the Voluntary movements of the Eyeballs, we are led to perceive that they are not so much *symmetrical* as *harmonious;* that is to say, the corresponding muscles on the two sides are rarely in action at once; whilst such a harmony or *consent* exists between the actions of the muscles of the two orbits, that they work to one common purpose, namely, the direction of both eyes towards the required object. They may be arranged under two groups; the first comprising those which are alike harmonious and symmetrical; the second including those which are harmonious but not symmetrical. To the *first* group belong the following.—1. *Both* eyeballs are *elevated,* by the contraction of the two Superior Recti.—2. *Both* eyeballs are *depressed,* by the conjoint action of the Inferior Recti muscles.—3. *Both* are drawn directly *inwards,* or *inwards* and *downwards,* as when we look at an object placed on or near the nose; this movement is effected by the action of the Internal Recti of the two sides, with or without the Inferior Recti. It is evidently symmetrical, but might seem at first sight not to be harmonious, because the eyes do not move together towards one side or the other; it is, however, really harmonious, since their axes are directed towards the same point.†—Now it is to be observed, with regard to these movements, that we can never effect them in antagonism with each other, or with those of other muscles. We cannot, for example, raise one eye and depress the other; nor can we raise or depress one eye, when we adduct or abduct the other. The explanation of this will be found in the fact, that we can never, by so doing, direct the eyes to the same point.—The harmonious but unsymmetrical movements, forming the *second* class, are those in which the Internal and External Recti of the two sides are made to act together, either alone, or in conjunction with the Superior and Inferior Recti. They are as follows.—4. *One* eye is made to revolve directly *inwards,* by the action of its Internal Rectus, whilst *the other* is turned *outwards* by the action of its External Rectus.—5. *One* eye is made to revolve *upwards* and *inwards,* by the conjoint action of the Superior and Internal Recti; *the other, upwards* and *outwards,* by the

* The Author has been informed by his friend Mr. Bowman, that he has met with two cases of double vision, in which the defect was not experienced when the head was held erect or turned upon its vertical axis, but only when it was inclined to the one shoulder or the other. Such a peculiarity is readily explained on the above hypothesis, by the supposition that one or both of the oblique muscles of one eye was paralysed, so that the normal rotation was not performed on that side.

† Some persons can effect this voluntarily to a greater extent than others; but even then, they can only accomplish it by fixing the gaze upon some object situated between the eyes; and cannot call the adductor muscles into combined action in perfect darkness, or if the lids be closed. Even those who have the least power of effecting this extreme convergence by at once directing the eyes towards a very near object, can accomplish it by looking at an object placed at a moderate distance, and gradually bringing this nearer to the nose, keeping the eyes steadily fixed upon it. The unwonted character of the movement is shown in this—that it can only be maintained, even for a short time, by a strong effort, producing a sense of fatigue.

conjoint action of the Superior and External Recti.—6. *One* eye is made to revolve *downwards* and *inwards*, by the conjoint action of the Inferior and Internal Recti; *the other*, *downwards* and *outwards*, by the conjoint action of the Inferior and External Recti.—In these movements, *two different* muscles, the External and Internal Recti, are called into action on the two sides, with or without the superior and inferior Recti; but they are so employed for the purpose of directing the axes of the eyes towards *the same* point; and although, as just noticed, we can put the two Internal Recti in action together, we cannot voluntarily cause the two External Recti to contract together, it not being possible that any object should be in such a position as to require this action for the direction of the axes of the eyes towards it.

918. The greater number of the foregoing movements may be performed even unconsciously to ourselves, in obedience to a voluntary determination to keep the direction of the eyes fixed, instead of to give motion to the eyeballs. Thus, if we gaze steadily at an object in front of us, and then depress the head forwards on its transverse axis, the eyeballs roll upwards upon their transverse axes (1) by the action of the Superior Recti, without our being aware of it; so if, whilst still maintaining the same fixed gaze, we raise the head into the vertical position and then depress it backwards, the eyeballs are rolled downwards (2) by the action of the Inferior Recti; if, under the same conditions, the head be made to rotate on its vertical axis from side to side, the eyeballs will be made to roll on their vertical axes in the contrary direction, by the External and Internal Recti (4) of the two sides respectively; so, by causing the head to move obliquely in the opposite directions, the oblique movements (5 and 6) of the eyeballs are made to take place by the continued fixation of the vision upon the same object. To these we have to add one more action, which cannot be called-forth in any other mode; namely, that rotation of the two eyes upon their antero-posterior axes, which takes place, probably by the instrumentality of the Oblique muscles, when we incline the head to one side or the other by rotating it upon its antero-posterior axis (§ 916). In all these movements, as in the preceding, the Will directs the *result;* and there is no other difference between them, than that which arises out of our consciousness of a change in the one case, and our unconsciousness in the other.—The truly Involuntary movements of the eyeballs, however, are performed under very different conditions; there being here no purposive direction or fixation of the gaze; and the muscular contractions not being determined by visual sensations, but being called-forth by nerve-force excited in some remote part. Of this we have an example in the normal revolution of both eyes upwards and inwards, which takes place in the acts of coughing, sneezing, winking, &c.; but many more abnormal movements of the eyeballs, in which there is neither harmony nor symmetry, present themselves in convulsive diseases.

919. It is a condition of single and distinct vision, that the *usual* axes of the eyes should be directed towards the object, in order that its picture should be thrown upon the parts of the two retinæ which are *accustomed* to act together (§ 886); and that this direction is afforded by the visual sensations which govern the muscular movements, the result of these merely being determined by the Will, seems sufficiently obvious from

the considerations now stated. The following circumstances, however, afford additional confirmation of this doctrine.—It is well known that, in children born blind, the movements are not harmonious; they are frequently very far from being so, in cases of congenital cataract, where a considerable amount of light is evidently admitted, but where no distinct image can be formed; and in such cases, the movements are most harmonious where the object is bright or luminous, and more vivid impressions are therefore made upon the retinæ. It is no objection to this doctrine to say, that persons who have become blind may still move their eyes in an harmonious manner; since, the habit of the association of particular movements having been once acquired, the guidance of the muscles may be effected by sensations derived from themselves, in the manner in which it takes place in the laryngeal movements of the deaf and dumb; and, as a matter of fact, a want of consent may often be observed where the blindness is total. The peculiar vacant appearance, which may be noticed in the countenances of persons, completely deprived of sight by amaurotic or other affections, which do not alter the external aspect of the eyes, seems to result from this,—that their axes are *parallel*, as if the individual were looking into distant space, instead of presenting that slight convergence, which must always exist between them, when the eyes are fixed upon a definite object. This convergence, which is of course regulated by the Internal Recti, varies in degree according to the distance of the object; and it is astonishing how minute an alteration in the axes of the eyes, is perceptible to a person observing them. For instance, A sees the eyes of B directed towards his face, but he perceives that B is *not looking* at him; he knows this by a sort of intuitive interpretation of the fact, that his face is not the point of convergence of B's eyes. But if B, who might have been previously looking at something nearer or more remote than A's face, fix his gaze upon the latter, so that the degree of the convergence of the axes is altered, without the general direction of the eyes being in the least affected, the change is at once perceived by the person so regarded; and the *eyes* of the two then *meet*.

920. The physiological principles which have now been stated, have an important application in the treatment of Strabismus by operation; a practice whose frequent want of success is due in great part to the injudicious selection of cases, and to the wrong measures pursued.—The degree in which habit accustoms parts of the retinæ that did not originally correspond, to work together harmoniously, is remarkably shown by the fact, that patients who have been long affected with Convergent Strabismus, and who see equally well with both eyes (as many do), are not troubled with double vision. On the other hand, when a person whose eyes look straight before him, is the subject of a disorder which renders their motions in any degree irregular, he is at once affected with double vision; and the same has been frequently noticed as an immediate result of the successful operation for the cure of strabismus, where vision is good in both eyes. Although the images were previously formed on parts of the retinæ which were very far from corresponding with each other, yet no sooner is the position of the eyes rectified (so that the relation between the situation of the images is the same as it would be in a sound eye), than the patient sees double. Now in these

cases the difficulty very speedily diminishes, and the patient soon learns to see single. That there is a *greater* tendency to consent between the images, however, when they are formed upon the parts of the two retinæ which normally correspond, may be freely admitted; and this seems to be a principle of some importance in determining the re-adjustment of the eyes, after the operation for Strabismus. This re-adjustment is not always immediate; for after the muscle has been freely divided, the eye often remains somewhat inverted for a few days, gradually acquiring its straight position. The Author has known one case, in which, after such a degree of temporary inversion as seemed to render the success of the operation very doubtful, eversion actually took place for a short time to a considerable extent; after which the axes became parallel, and have remained so ever since.—Another argument, derived from the results of this operation, in favour of the consensual movement being chiefly regulated by the correspondence in the seats of the impressions on the two retinæ, is, that it is much more successful in those cases in which the sight of the most displaced eye is good, than in those in which (as not unfrequently happens from long disuse) it is much impaired. In cases of the latter class, the cure is seldom complete. There is another curious fact, which may be adverted to in reference to this subject: Strabismus not unfrequently arises from the presence of an opaque spot on the centre of the cornea, which prevents the formation of any images on the retina, except by the oblique rays; and nature seems to endeavour (so to speak) to repair the mischief, by causing the eye to assume the position most favourable for the reception of these.*

* In reference to this subject the Author would add that he is well convinced, from repeated observation, that those Surgeons are in the right, who have maintained that, in a large proportion of cases, strabismus is caused by an affection of *both* sets of muscles or nerves, and not of one only; and that it then requires, for its perfect cure, the division of the corresponding muscle on both sides. Cases will be frequently met with, in which this is evident; the two eyes being employed to nearly the same extent, and the patient giving to both a slight inward direction, when desired to look straight forwards. In general, however, one eye usually looks straight forwards, whilst the other is greatly inverted; and the sight of the inverted eye is frequently affected to a considerable degree by disuse; so that, when the patient voluntarily rotates it into its proper axis, his vision with it is far from being distinct. Some Surgeons have maintained, that the inverted eye is usually the only one in fault, and consider that the division of the tendon of its Internal Rectus is sufficient for the cure. They would even divide its other tendons, if the parallelism be not restored, rather than touch the other eye. The Author is himself satisfied, however, that the restriction of the abnormal state to a single eye, is the exception, and not the rule, in all but very slight cases of strabismus; and to this opinion he is led both by the consideration of the mode in which strabismus first takes place, and by the results of the operations which have come under his notice. If the eyes of an infant affected with cerebral disease be watched, there will frequently be observed in them very irregular movements; the axes of the two being sometimes extremely convergent, and then very divergent. This irregularity is rarely or never seen to be confined to one eye. Now, in a large proportion of cases of Strabismus, the malady is a consequence of some cerebral affection during infancy or childhood, which we can scarcely suppose to have affected one eye only. Again, in other instances we find the Strabismus to have resulted from the constant direction of the eyes to very near objects, as in short-sighted persons; and here, too, the cause manifestly affects both.—Now it is easy to understand, why one eye of the patient should *appear* to be in its natural position, whilst the other is greatly inverted. The cause of strabismus usually affects the two eyes somewhat unequally, so that one is much more inverted than the other. We will call the least inverted eye A, and the other B. In the ordinary acts of vision, the patient will make most use of the least inverted eye, A, because he can most readily look straight forwards or outwards with it; but to bring it into the axis, or to rotate it outwards, necessitates a still more

### 3. *Energy and Rapidity of Muscular Contraction.*

921. The energy of Muscular contraction is of course to be most remarkably observed in those instances in which the continual exercise of particular parts has occasioned an increased determination of blood towards them, and in consequence a permanent augmentation in their bulk. This has been the case, for example, with persons who have gained their livelihood by exhibiting feats of strength. Much will, of course, depend on the mechanically-advantageous application of muscular power; and in this manner, effects may be produced, even by persons of ordinary strength, which would not have been thought credible. In lifting a heavy weight in each hand, for example, a person who keeps his back perfectly rigid, so as to throw the pressure vertically upon the pelvis, and only uses the powerful extensors of the thigh and calf, by straightening the knees (previously somewhat flexed), and bringing the leg to a right angle with the foot, will have a great advantage over one who uses his lumbar muscles for the purpose. A still greater advantage will be gained, by throwing the weight more directly upon the loins, by means of a sort of girdle, shaped so as to rest upon the top of the sacrum and the ridges of the ilia; and by pressing with the hands upon a frame, so arranged as to bring the muscles of the arms to the assistance of those of the legs: in this manner, a single Man, of ordinary strength, may raise a weight of 2000 lbs.; whilst few who are unaccustomed to such exertions, can lift more than 300 lbs. in the ordinary mode. A man of great natural strength, however, has been known to lift 800 lbs. with his hands; and the same individual performed several other curious feats of strength, which seem deserving of being here noticed. "1. By the strength of his fingers, he rolled up a very large and strong pewter dish. 2. He broke several short and strong pieces of tobacco-pipe, with the force of his middle finger, having laid them on the first and third finger. 3. Having thrust in under his garter the bowl of a strong tobacco-pipe, his legs being bent, he broke it to pieces by the tendons of his hams, without

decided inversion of B. This remains the position of things,—the patient usually looking straight forwards with A, which is the eye constantly employed for the purposes of vision,—and frequently almost burying under the inner canthus the other eye, B, the vision in which is of very little use to him. When, therefore, the tendon of the internal rectus of B is divided, the relative position of the two is not entirely rectified. Sometimes it appears to be so for a time; but the strabismus then begins to return, and it can only be checked by division of the tendon of the other eye, A; after which, the cure is generally complete and permanent. That it has not been so, in many of the patients on whom operations have been performed, the Author attributes, without the slightest doubt in his own mind, to the neglect of the second operation. As just now stated, the sight of the most inverted eye is frequently very imperfect; indeed it is sometimes impaired to such an extent, that the patients speak of it as entirely useless. That this impairment results in part from disuse merely, seems very evident, from the great improvement which often succeeds the rectification of the axes. The Author cannot help thinking it probable, however, that the same cause which produced the distortion of the eye may, in some instances at least, have affected the Optic nerve, as well as the Motor nerves of the orbit; and this idea seems borne out by the asserted restoration of sight, in certain cases of Amaurosis, by division of one or more tendons, where no Strabismus previously existed (See Adams "On Muscular Amaurosis").—A valuable memoir on the Operation for Strabismus, founded on the results of about 1000 cases, will be found in the "Philadelphia Medical Examiner," vol. vii., and an abstract of it in the "Brit. and For. Med.-Chir. Review," July, 1852, p. 262.

altering the bending of the knee. 4. He broke such another bowl between his first and second fingers, by pressing them together sideways. 5. He lifted a table six feet long, which had half a hundred-weight hanging at the end of it, with his teeth, and held it in that position for a considerable time. It is true, the feet of the table rested against his knees; but, as the length of the table was much greater than its height, that performance required a great strength to be exerted by the muscles of his loins, neck, and jaws. 6. He took an iron kitchen poker, about a yard long, and three inches in circumference, and, holding it in his right hand, he struck it on his bare left arm between the elbow and the wrist, till he bent the poker nearly to a right angle. 7. He took such another poker, and, holding the ends of it in his hands, and the middle of it against the back of his neck, he brought both ends of it together before him; and, what was yet more difficult, he pulled it straight again."* Haller mentions an instance of a man, who could raise a weight of 300 lbs., by the action of the elevator muscles of his jaw: and that of a slender girl, affected with tetanic spasm, in whom the extensor muscles of the back, in the state of tonic contraction or opisthotonos, resisted a weight of 800 lbs., laid on the abdomen with the absurd intention of straightening the body. It is to be recollected, that the mechanical application of the power developed by muscular contraction, to the movement of the body, is very commonly disadvantageous as regards *force*; being designed to cause the part moved to pass over a much greater *space* than that through which the muscle contracts. Thus the Temporal muscle is attached to the lower jaw, at about one-third of the distance between the condyle and the incisors; so that a shortening of the muscle to the amount of half an inch, will draw up the front of the jaw through an inch and a half; but a power of 900 lbs. applied by the muscle, would be required to raise 300 lbs. bearing on the incisors. In the case of the fore-arm and leg, the disproportion is much greater; the points of attachment of the muscles, by which the knee and elbow-joints are flexed and extended, being much closer to the fulcrum, in comparison with the distance of the points on which the resistance bears.

922. The rapidity of the changes of position of the component particles of muscular fibres, may, as Dr. Alison justly remarks,† be estimated, though it can hardly be conceived, from various well-known facts. The pulsations of the heart can sometimes be distinctly numbered in children, at more than 200 in the minute; and as each contraction of the ventricles occupies only one-third of the time of the whole pulsation, it must

* "Desaguliers' Philosophy," vol. ii.—The energy of muscular contraction appears to be greater in Insects, in proportion to their size, than it is in any other animals. Thus a Flea has been known to leap sixty times its own length, and to move as many times its own weight. The short-limbed Beetles, however, which inhabit the ground, manifest the greatest degree of muscular power. The *Lucanus cervus* (Stag Beetle) has been known to gnaw a hole of an inch in diameter, in the side of an iron canister in which it had been confined. The *Geotrupes stercorarius* (Dung or shard-born Beetle) can support uninjured, and even elevate, a weight equal to at least 500 times that of its body. And a small *Carabus* has been seen to draw a weight of 85 grains (about 24 times that of its body) up a plane of 25°; and a weight of 125 grains (36 times that of its body) up a plane of 5°; and in both these instances the friction was considerable, the weights being simply laid upon a piece of paper, to which the insect was attached by a string.

† "Cyclopædia of Anatomy and Physiology," Art. 'Contractility.'

be accomplished in 1-600th of a minute, or 1-10th of a second. Again, it is certain that, by the movements of the tongue and other organs of speech, 1500 letters can be distinctly pronounced by some persons in a minute: each of these must require a separate contraction of muscular fibres; and the production and cessation of each of the sounds, implies that each separate contraction must be followed by a relaxation of equal length; each contraction, therefore, must have been effected in 1-3000th part of a minute, or in 1-50th of a second. Haller calculated that, in the limbs of a dog at full speed, muscular contractions must take place in less than the 1-200th of a second, for many minutes at least in succession. —All these instances, however, are thrown into the shade, by those which may be drawn from the class of Insects. The rapidity of the vibrations of the wings may be estimated from the musical tone which they produce; it being easily ascertained by experiments, what number of vibrations are required to produce any note in the scale (§ 908). From these data, it appears to be the necessary result, that the wings of many Insects strike the air *many hundred*, or even *many thousand*, times in every *second.*— The minute precision with which the degree of muscular contraction can be adapted to the designed effect, is in no instance more remarkable than in the Glottis. The musical pitch of the tones produced by it, is regulated by the degree of tension of the *chordæ vocales*, which are possessed of a very considerable degree of elasticity (§ 928). According to the observations of Müller,* the average length of these, in the male, in a state of repose, is about 73-100ths of an inch; whilst, in the state of greatest tension it is about 93-100ths; the difference being therefore 20-100ths, or one-fifth of an inch: in the female glottis, the average dimensions are about 51-100ths, and 63-100ths respectively; the difference being thus about one-eighth of an inch. Now the natural compass of the voice, in most persons who have cultivated the vocal organ, may be stated at about two octaves, or 24 semitones. Within each semitone, a singer of ordinary capability could produce at least ten distinct intervals; so that of the total number, 240 is a very moderate estimate. There must, therefore, be at least 240 different states of tension of the vocal cords, every one of which is producible by the will, without any previous trial; and the *whole* variation in the length of the cords being not more than one-fifth of an inch, even in man, the variation required to pass from one interval to another, will not be more than 1-1200th of an inch. And yet this estimate is much below that, which might be truly made from the performances of a practised vocalist.†

### 4. *Of the Influence of Expectant Attention on Muscular Movements.*

923. There is a very curious group of involuntary muscular movements, not yet specially considered, which may be ranked under the general category of *ideo-motor* actions; being induced by the state of *expectant*

* "Elements of Physiology," Baly's translation, p. 1018.

† It is said that the celebrated Madc. Mara was able to sound 100 different intervals between each tone. The compass of her voice was at least three octaves, or 21 tones; so that the total number of intervals was 2100, all comprised within an extreme variation of one-eighth of an inch; so that it might be said that she was able to determine the contractions of her vocal muscles to nearly the seventeen-thousandth of an inch.

*tention*, in which the mind is fully possessed with the idea that a certain :tion will take place, and is eagerly looking-out for its occurrence. Such ovements are well known to occur in the muscles connected with the ·ganic functions, and are among the means by which important modifi- tions are produced in those functions by the direction of the mind to ·em. Thus, as Dr. Holland has remarked, "the action of the heart is ten quickened or otherwise disturbed by the mere centring the con- iousness upon it, without any emotion or anxiety. On occasions where s beats are audible, observation will give proof of this, or the physician ın very often infer it while feeling the pulse; and where there is liability › irregular pulsation, such action is seemingly brought on, or increased, ỵ the effort of attention, even though no obvious emotion be present." The same may be said of the parts concerned in respiration. If this :t be expressly made the subject of consciousness, it will be felt to ndergo some change; generally to be retarded at first, and afterwards .uickened." "The act of swallowing, again, becomes manifestly embar- ·ıssed, and is made more difficult by the attention fixed upon it when ıe morsel to be swallowed comes into contact with the part."* And ıere can be no doubt that the movements of the lower part of the .imentary canal are capable of being affected in a similar manner, since e may frequently trace the rapid descent of the fæcal mass into the :ctum, when we expect to be shortly able to discharge it; and it is in reat part in this mode, that *habit* operates, in producing a readiness for efecation at particular times, and that bread-pills and other supposi- tious purgatives unload the bowels.†

924. But it is with the involuntary movements produced by the same gency in the muscles ordinarily accounted voluntary, that we are at resent especially concerned. This is a very curious subject of inquiry, and ıe to which adequate attention has scarcely yet been given; the pheno- ıena which are referable to the principle of action just enunciated, aving been very commonly explained by the agency of some other force.

* See Dr. Holland's "Chapters on Mental Physiology," pp. 16–19.

† The Author may mention the two following cases, which have fallen within his own nowledge, as curious illustrations of the influence of mental states upon the movements of the limentary canal.—The first of these occurred in the person of a literary man, of a some- ·hat hypochondriacal temperament, who had been troubled with continual costiveness, for hich he had been accustomed to take an aperient pill daily. Finding that this ceased to ave its usual effect, and being fearful of increasing his regular dose, he applied for advice to practitioner, who, having had former experience of what mental agency alone would do, etermined to try its effect in this instance. Seating his patient before him, with the abdo- ıen uncovered, he desired him to fix his attention intently upon his abdominal sensations, nd assured him that in a short time he was quite certain that he would begin to feel a ıovement in his bowels, which would end in a copious evacuation. He himself did nothing ·ut look steadily at his patient, with an air of great determination and confidence, and point .is finger at the abdomen, moving it along the arch of the colon, and (as it were) in the ourse of the convolutions of the small intestines, so as to aid the patient in fixing his atten- ion upon them. In a short time the expected movements were felt, and a copious evacua- ion soon followed; and for some time afterwards, the bowels continued to act freely without nedicine.—In the other case, a Lecturer at a public Institution was seized with a strong npulse to defecation during his lecture; and was greatly inconvenienced by the effort neces- ary to restrain it. Before every subsequent lecture in the same place, the same impulse eturned upon him, notwithstanding that he might have previously unloaded his bowels else- vhere. In this case, there was obviously a state of apprehension combined with the simple nticipation; but the influence of the latter is shown by the fact, that in no other place did his individual experience the impulse in question under the like circumstances.

Thus, if a button or ring be suspended from the end of the finger or thumb, in such a position that, when slightly oscillating, it shall strike against a glass tumbler, it has been affirmed by many who have made the experiment, that the button continues to swing with great regularity, striking the glass at tolerably regular intervals, until it has sounded the hour of the day, after which it ceases for a time to swing far enough to make another stroke. This certainly does come to pass, in many instances, without any intention on the part of the performer; who may, in fact, be doing all in his power to keep his hand perfectly stationary. Now it is impossible, by any voluntary effort, to keep the hand absolutely still, for any length of time, in the position required; an involuntary tremulousness is always observable in the suspended body; and if the attention be fixed upon the part, with the expectation that the vibrations will take a determinate direction, they are very likely to do so.* Their persistence in this direction, however, *only takes place so long as they are guided by the visual sensations;* a fact which at once points to the real spring of their performance. When the performer is impressed with the conviction that the hour *will* be thus indicated, the result is very likely to happen; and when it has once occurred, his confidence is sufficiently established to make its recurrence a matter of tolerable certainty. On the other hand, the experiment seldom succeeds with sceptical subjects; the expectant idea not having in them the requisite potency. That it is through the mind that these movements are regulated, however involuntarily, appears evident from these two considerations; first, that if the performer be entirely ignorant of the hour, the strokes on the glass do not indicate its number, except by a casual coincidence; and second, that the division of the entire period of the earth's rotation into twenty-four hours, and the very nomenclature of these hours, being entirely arbitrary and conventional, cannot be imagined to operate in any other mode.† These phenomena, in which no hypothetical 'odylic' or other concealed agency can be reasonably supposed to operate, are here alluded-to only for the sake of illustrating those next to be described, which have been imagined to prove the existence of a new force in Nature.—If "a fragment of anything, of any shape," be suspended from the end of the fore-finger or thumb, and the attention be intently fixed upon it, regular oscillations will be frequently seen to take place in it; and if changes of various kinds be made in the conditions of the experiment, by placing bodies of different sorts beneath the pendulum, or by the contact of different persons or things with the person of the suspender, corresponding changes in the direction of the movements will very commonly take place.‡ Now this will occur, notwithstanding the strong desire of the experimenter to maintain a com-

* This was long since pointed out by M. Chevreul, who investigated the subject in a truly philosophic spirit. See his letter to M. Ampère, in the "Dublin Journal of Medical and Chemical Science," vol. iv.

† For instance, the button which strikes *eleven* at night in London, should strike *twenty-three* in Rome, where the cycle of hours is continued through the whole twenty-four hours; and if an Act of Parliament were to introduce the Italian horary arrangement into this country, all the swinging buttons in her Majesty's dominions would have to add twelve to their number of post-meridiem strokes; all which would doubtless come to pass, if the experimenters' faith in the result were sufficiently strong.

‡ See Dr. H. Mayo on "The Truths contained in Popular Superstitions," 3rd edition, Letter xii.

ete immobility in the suspending finger; but it is very easily proved hat the movements are guided by his visual sensations, and that the mpulse to them is entirely derived from his expectation of a given result. For, if he close his eyes, or withdraw them from the vibrating body, its oscillations (as in the previous case) immediately lose their constancy; manifestly proving that the influence which directs them acts through his consciousness. And, again, if he be ignorant of the change which is made n the conditions of the experiment, and should expect or guess something different from that which really exists, the movement will be in accordance with *his idea*, not with the reality.*—Thus, then, we have here most distinct proof that a state of mind exists, which is neither volitional nor emotional, but which consists in the complete engrossment of the attention by a fixed idea, whereby definite muscular movements are produced, in spite of a determined exertion of the Will. The Will is concerned, however, in the induction of the mental state in question, by the fixation of the attention on the oscillating body; and it is only in those individuals who possess the power of voluntary abstraction (§ 823) to a considerable extent, that the experiment is likely to succeed. It is scarcely necessary to add, that as *faith* in its results is essential to their production, those who are acquainted with the mode in which they are really brought about, are not likely to be good subjects for it.

925. It is doubtless on the very same physiological principle, that we are to explain the mysterious phenomena of the 'Divining-Rod,' which have been accepted as true, or rejected as altogether fabulous, according to the previous habits of thought of those who have given their attention to the subject. Now that the end of a hazel-fork, whose limbs are grasped firmly in the hands of a person whose good faith can scarcely be doubted, frequently points upwards or downwards without any intentional direction on his part, and often thus moves when there is metal or water beneath the surface of the ground at or near the spot, is a fact which is vouched-for by such testimony that we have scarcely a right to reject it; and when we come to examine into the conditions of the occurrence, we shall find that they are such as justify us in attributing it to a state of *expectant attention*, which (as we have seen) is fully competent to induce muscular movement. For, in the first place, as not above one individual in forty, even in the localities where the virtues of the

* A most remarkable and convincing exemplification of this fact, is afforded by Dr. Henry Madden's experiments with Mr. Rutter's "Magnetometer," at Brighton, as detailed in the "Lancet" for Nov. 15, 1851.—Dr. Madden had satisfied himself, in the first instance, that the vibrations of the suspended body were affected by the reception, into his other hand, of homœopathic globules, whose differences of composition were indicated by corresponding changes in the direction of the oscillations. But having been led to re-examine the question, and to apply that test which he ought to have employed from the first,—namely, to have various globules put into his hand, without being himself made aware of their composition,—he found that the results entirely lost their previous constancy, which was thus evidently due to his expectation of a particular movement in each case. It is a manifestation of the very imperfect analysis which is commonly made of such phenomena, that, from the moment when they are found referable to a physiological principle, instead of demonstrating (as they were at first supposed to do) the existence of a new force, they seem to lose all their interest for those who had previously watched them with eagerness, and to be set down as illusory, or as the product of the "imagination;" notwithstanding that they are as real in the one case as in the other, and are not in any degree less curious and interesting when considered under the former aspect, than when viewed in the latter.

divining-rod are still held as an article of faith, is found to succeed in the performance of this experiment, it is obvious that the agency, whatever be its nature, which produces the deflections, must operate by affecting the holder of the rod, and not by attracting or repelling the rod itself. And when experiments are carefully made with the view of determining the nature of this agency, they are found to indicate most clearly that the state of expectant attention, induced by the anticipation of certain results, is fully competent to produce them. For the mere act of holding the rod for some time in the required position, and of attending to its indications, is sufficient to produce a tendency to spasmodic contraction in the grasping muscles, notwithstanding a strong effort of the will to the contrary; and when, by such contractions, the limbs of the fork are made to approximate towards or to separate from each other, the point of the fork will be caused to move either upwards or downwards, according to the position in which it is held. If, when the muscles have this tendency to contract, occasioned by their continued restraint in one position, the mind be possessed with the expectation that a certain movement will ensue, that movement will actually take place, even though a strong effort may be made by the Will to prevent any change in the condition of the muscles. And a sufficient ground for such expectation exists, on the part of those who are possessed with the idea of the peculiar powers of the divining-rod, in the belief, or even in the surmise, that water or metal may be beneath particular points of the surface over which they pass.*— Until, therefore, it shall have been proved by an extended course

* This was admitted even by Dr. H. Mayo, notwithstanding his belief in the existence of an 'Od-force,' governing the movements of the divining-rod. For he found in the course of his experiments, that when his 'diviner' knew which way he expected the fork to move, it invariably answered his expectations; but when he had the man blindfolded, the results were uncertain and contradictory. Hence he became certain that several of those in whose hands the divining-rod moves, set it in motion, and direct its motion (however unintentionally and unconsciously) by the pressure of their fingers, and by carrying their hands nearer-to or apart-from each other. (See his Letters "On the Truths contained in Popular Superstitions," Letter I.)—The following statement of the results obtained by a very intelligent friend of the Author, who took up the inquiry some years ago, with a strong prepossession (derived from the assurances of men of high scientific note) in favour of the reality of the supposed influence, but yet with a desire to investigate the whole matter carefully and philosophically for himself, will serve as a complete illustration of the doctrine enunciated above. Having duly provided himself with a hazel fork, he set out upon a survey of the neighbourhood in which he happened to be staying on a visit; this district was one known to be traversed by mineral veins, with the direction of some of which he was acquainted. With his 'divining-rod' in his hand, and with his attention closely fixed upon his instrument of research, he walked forth upon his experimental tour; and it was not long before, to his great satisfaction, he observed the point of the fork to be in motion, at the very spot where he knew that he was crossing a metallic lode. For many less cautious investigators, this would have been enough; but it served only to satisfy this gentleman that he was a favourable subject for the trial, and to stimulate him to further inquiry. Proceeding in his walk, and still holding his fork *secundum artem*, he frequently noticed its point in motion, and made a record of the localities in which this occurred. He repeated these trials on several consecutive days, until he had pretty thoroughly examined the neighbourhood, going over some parts of it several times. When he came to compare and analyse the results, he found that there was by no means a satisfactory accordance amongst them; for there were many spots over which the rod had moved on one occasion, at which it had been obstinately stationary on others, and *vice versâ;* so that the constancy of a physical agency seemed altogether wanting. Further, he found that whilst some of the spots over which the rod had moved, were those known to be traversed by mineral veins, there were many others in which its indications had been no less positive, but in which those familiar with the mining geology

carefully-conducted experiments, that this mode of explanation is ıadequate to account for the phenomena in question, all that is genuine what is at present known may be set down to the category of Ideo-ıotor actions, or reflex actions of the Cerebrum (§ 683).

926. To this same category are doubtless to be referred a large number those actions of Mesmeric 'subjects,' which have been considered by ›me as most unequivocal indications of the existence of an agency *sui eneris,* whilst by others they have been regarded as the results of inten-onal deception. Now many of them are of a kind which the Will *could* ot feign, being violent convulsive movements, such as no voluntary fort could produce; but the Mesmeric 'subject' being previously pos-ssed with the expectation that certain results will follow certain ac-ons (as, for instance, that convulsive movements will be brought-on y touching a piece of mesmerized metal), and the whole nervous power eing concentrated, as it were, upon the performance, the movements ›llow when the subject *believes* the conditions to have been fulfilled, hether they *have* been, or not. These facts were most completely esta-lished by the commission appointed to investigate the pretensions of Iesmer himself; and whilst they demonstrate the unreality of the sup-osed mesmeric influence (so far, at least, as this class of phenomena is oncerned), they also prove the position here contended for, namely, the ufficiency of the state of *expectant attention,* in those whose minds can be ompletely possessed by it, to produce effects of the same nature with hose which are induced in Hysterical subjects by emotional excite-ıent.*

the neighbourhood were well assured that no veins existed. On the other hand, the rod ad remained motionless at many points where it *ought* to have moved, if its direction had een affected by any kind of terrestrial emanation. These facts led the experimenter to a rong suspicion that the cause existed in himself alone; and carrying out his experiments ill further, he ascertained that he could not hold the fork in his hand for many minutes ›nsecutively, concentrating his attention fixedly upon it, without an alteration in the direc-ion of its point, in consequence of an involuntary though almost imperceptible movement of is hands; so that in the greater number of instances in which the rod exhibited motion, the henomenon was clearly attributable to this cause, and it was a matter of pure accident hether the movement took place over a mineral vein, or over a blank spot. But further, he scertained on a comparison of his results, that the movement took place more frequently here he knew or suspected the existence of mineral veins, than in other situations; and hus he came, without any knowledge of the theory of *expectant attention,* to the practical onclusion that the actions of his nerves and muscles were in great degree regulated by the deas which possessed his mind.

* On the whole of this subject the Author has the satisfaction of referring to the essay n 'The Effects of Attention on Bodily Organs,' in Dr. Holland's "Chapters on Mental hysiology," as showing the essential coincidence between the opinions of this distinguished hysician, and those at which he had himself arrived by independent inquiry.

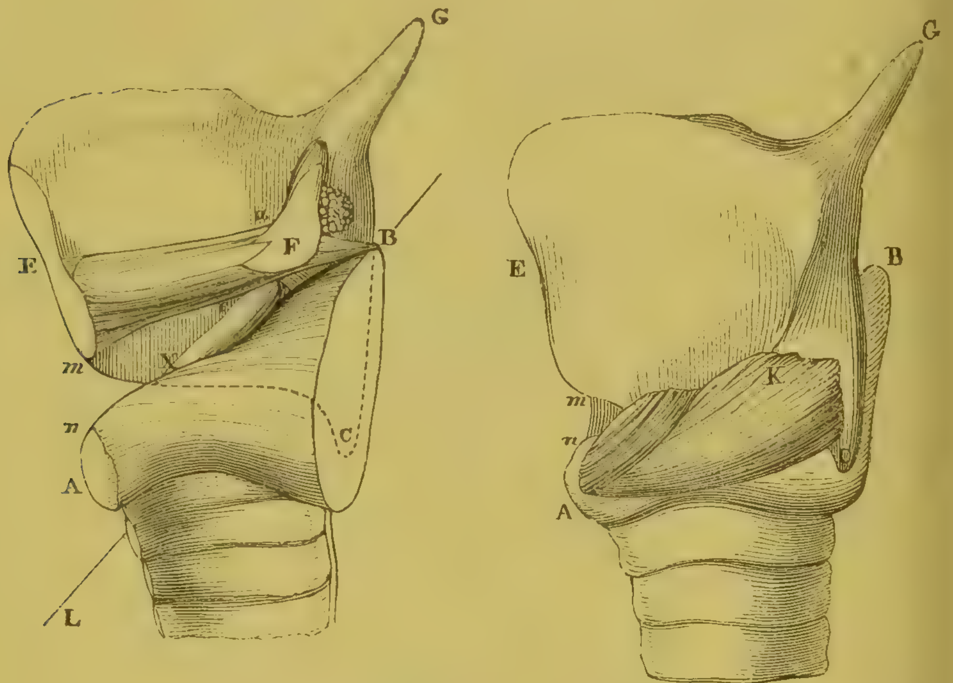
# CHAPTER XVII.

## OF THE VOICE AND SPEECH.

### 1.—*Of the Larynx, and its Actions.*

927. THE sounds produced by the organ of Voice constitute the most important means of communication between Man and his fellows; and the power of Speech has, therefore, a primary influence, as well on his physical condition, as on the development of his mental faculties. In order to understand the nature of this organ as a generator of Sound, it is requisite to inquire, in the first instance, into the sources from which sounds at all corresponding to the Human voice are elsewhere obtained. It is necessary to bear in mind, that Vocal sounds, and Speech or articulate language, are two things entirely different; and that the former may

FIG. 146.



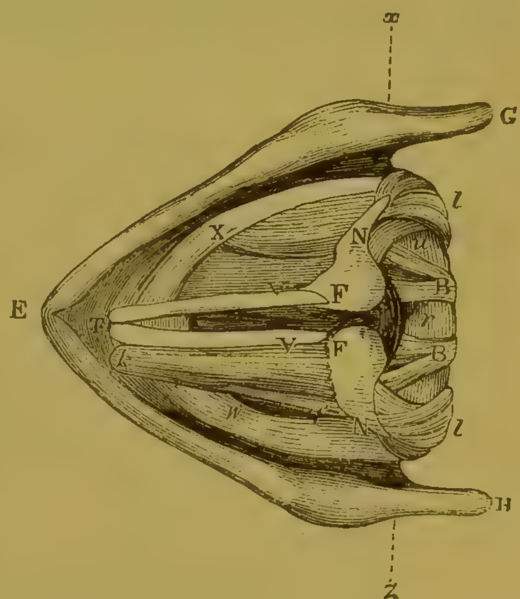

External and Sectional views of the *Larynx*:—A *n* B, the cricoid cartilage; E C G, the thyroid cartilage; G, its upper horn; C, its lower horn, where it is articulated with the cricoid; F, the arytenoid cartilage; E, F, the vocal ligament; A K, crico-thyroideus muscle; F *e m*, thyro-arytenoideus muscle; X *e*, crico-arytenoideus lateralis; *s*, transverse section of arytenoideus transversus; *m n*, space between thyroid and cricoid; B L, projection of axis of articulation of arytenoid with thyroid.

be produced in great perfection, where there is no capability for the latter. Hence we should at once infer, that the instrument for the production of vocal sounds was distinct from that by which these sounds are modified into articulate speech; and this we easily discover to be the case, the voice being unquestionably produced in the larynx, whilst the modifications of it by which language is formed, are effected for the most part in

he oral cavity.—The structure and functions of the former, then, first laim our attention.

928. It will be remembered that the Trachea is surmounted by a stout artilaginous annulus, termed the *Cricoid* cartilage; which serves as a undation for the superjacent mechanism. This is embraced (as it were) y the *Thyroid,* which is articulated to its sides by its lower horns, round he extremities of which it may be regarded as turning, as on a pivot. In his manner the lower front border of the thyroid cartilage, which is ordiarily separated by a small interval from the upper margin of the cricoid, nay be made to approach it or recede from it; as any one may easily scertain, by placing his finger against the little depression which may be eadily felt externally, and observing ts changes of size, whilst a range of lifferent tones is sounded; for it will hen be noticed that, the higher the ote, the more the two cartilages are nade to approximate, whilst they eparate in proportion to the depth of the tones.* Upon the upper surace of the back of the cricoid, are eated the two small *Arytenoid* cartiages; these are fixed in one direcion by a bundle of strong ligaments, vhich tie them to the back of the ricoid; but they have some power of moving in other directions, upon a ind of articulating surface. The diection of the surface, and the mode n which these cartilages are othervise attached, cause their movement o be a sort of rotation in a plane vhich is nearly horizontal but partly lownwards; so that their vertical lanes may be made to separate from ach other, and at the same time to ssume a slanting position. This hange of place will be better understood, when the action of the muscles is described. To the summit of he arytenoid cartilages are attached the *chordæ vocales* or Vocal Liganents, which stretch across to the front of the thyroid cartilage; and it s upon the condition and relative situation of these ligaments, that their ction depends. It is evident that they may be rendered more or less ense, by the movement of the Thyroid cartilage just described; being ightened by the depression of its front upon the Cricoid cartilage, and lackened by its elevation. On the other hand, they may be brought nto more or less close apposition, by the movement of the Arytenoid artilages; being made to approximate nearly, or to recede in such a nanner as to cause the rima glottidis to assume the form of a narrow V,

Fig. 147.



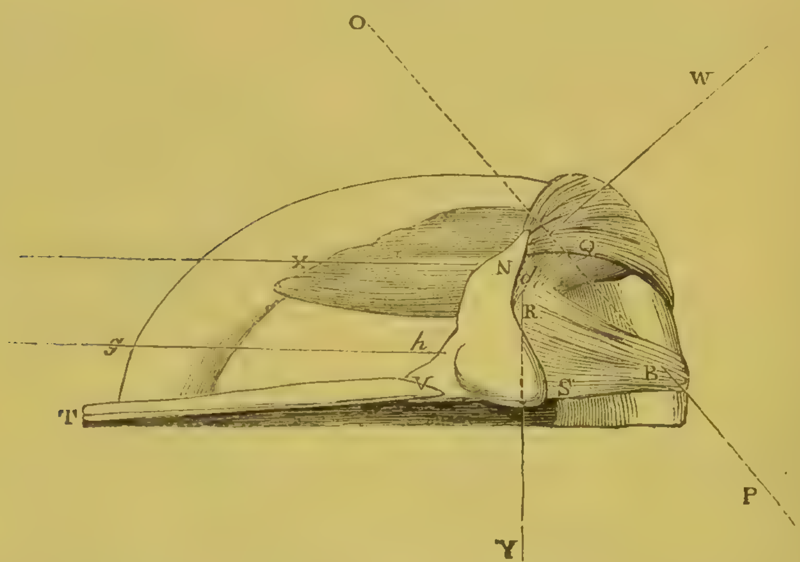

Bird's-eye view of *Larynx* from above:—G E H, the thyroid cartilage, embracing the ring of the cricoid *r u* X *w*, and turning upon the axis *x z*, which passes through the lower horns, C, Fig. 146; N F, N F, the arytenoid cartilages, connected by the arytenoideus transversus; T V, T V, the vocal ligaments; N X, the right crico-arytenoideus lateralis (the left being removed); V *k f*, the left thyro-arytenoideus (the right being removed); N *l*, N *l*, the crico-arytenoidei postici; B, B, the crico-arytenoid ligaments.

* In making this observation, it is necessary to put out of view the general movement to he larynx itself, which the finger must be made to follow up and down.

by the revolution of these cartilages.—We shall now inquire into the actions of the muscles upon the several parts of this apparatus; and first into those of the larynx alone.

929. The depression of the front of the thyroid cartilage, and the consequent *tension* of the Vocal Ligaments, is occasioned by the conjoint action of the *Crico-thyroidei* on both sides; and the chief antagonists to these are the *Thyro-arytenoidei*, which draw the front of the thyroid back towards the arytenoid cartilages, and thus *relax* the vocal ligaments. These two pairs of muscles may be regarded as the principal governors of the *pitch* of the notes, which, as we shall hereafter see, is almost entirely regulated by the tension of the ligaments; their action is assisted, however, by that of other muscles presently to be mentioned.—The arytenoid cartilages are made to diverge from each other, by means of the *Crico-arytenoidei postici* of the two sides, which proceed from their outer

FIG. 148.




Part of Fig. 147 enlarged, to show the *Direction of the Muscular Forces* which act on the Arytenoid cartilage:—Q N V S, the right Arytenoid cartilage; T V, its vocal ligament; B R S, bundle of ligaments uniting it to Cricoid; O P, projection of its axis of articulation; *h g*, direction of the action of the Thyro-arytenoideus; N X, direction of Cryco-arytenoideus lateralis; N W, direction of Crico-arytenoideus posticus; N Y, direction of Arytenoideus transversus.

corners, and turn somewhat round the edge of the Cricoid, to be attached to the lower part of its back; their action is to draw the outer corners backwards and downwards, so that the points to which the vocal ligaments are attached, are separated from one another, and the rima glottidis is thrown *open*. This will be at once seen from the preceding diagram, in which the direction of traction of the several muscles is laid down.—The action of these muscles is partly antagonized by that of the *Crico-arytenoidei laterales,* which run forwards and downwards from the outer corners of the Arytenoid cartilages, and whose action is to bring the anterior points of the arytenoid cartilages into the same straight line, at the same time depressing them, so as thus to *close* the glottis. These muscles are assisted by the *Arytenoideus transversus,* which connects the posterior faces of the Arytenoid cartilages, and which, by its contraction, draws them together. By the conjoint action, therefore, of the Crico-

arytenoidei laterales and of the Arytenoideus transversus, the whole of the adjacent faces of the Arytenoid cartilages will be pressed together, and the points to which the vocal ligaments are attached will be depressed.—But if the Arytenoideus be put in action in conjunction with the Crico-arytenoidei postici, the tendency of the latter to separate the Arytenoid cartilages being antagonised by the former, its backward action only will be exerted; and thus it may be caused to aid the Crico-thyroidei in rendering tense the vocal ligaments. This action will be further assisted by the *Sterno-thyroidei*, which tend to depress the Thyroid cartilage, by pulling from a fixed point below;* and the *Thyro-hyoidei* will be the antagonist of these, when they act from a fixed point above, the Os Hyoides being secured by the opposing contraction of several other muscles.—The respective actions of these muscles will be best comprehended by the following Table.

*Govern the pitch of the notes.*

| | | |
|---|---|---|
| Antagonists. | CRICO-THYROIDEI<br>STERNO-THYROIDEI | Depress the front of the Thyroid cartilage on the Cricoid, and *stretch* the vocal ligaments; assisted by the Arytenoideus and Crico-arytenoidei postici. |
| | THYRO-ARYTENOIDEI<br>THYRO-HYOIDEI | Elevate the front of the Thyroid cartilage, and draw it towards the Arytenoids, *relaxing* the vocal ligaments. |

*Govern the Aperture of the Glottis.*

| | | |
|---|---|---|
| Antagonists. | CRICO-ARYTENOIDEI POSTICI | *Open* the Glottis. |
| | CRICO-ARYTENOIDEI LATERALES<br>ARYTENOIDEUS TRANSVERSUS | Press together the inner edges of the Arytenoid cartilages, and *close* the Glottis. |

930. The muscles which stretch or relax the Vocal ligaments, are entirely concerned in the production of Voice; those which govern the aperture of the Glottis have important functions in connection with the Respiratory actions in general, and stand as guards (so to speak) at the entrance to the lungs. Their separate actions are easily made evident. In the ordinary condition of rest, it seems probable that the Arytenoid cartilages are considerably separated from each other; so as to cause a wide opening to intervene between their inner faces, and between the vocal ligaments, through which the air freely passes; and the vocal ligaments are at the same time in a state of complete relaxation.—We can close the aperture of the Glottis by an exertion of the will, either during inspiration or expiration; and its closure by an automatic impulse forms part of the acts of Coughing and Sneezing (§ 555), besides giving rise to those more prolonged impediments to the ingress and egress of air, which have been already noticed as resulting from disordered states of the Nervous system (§ 849, XVII.). With these actions, the muscles which regulate the tension of the vocal ligaments have nothing to do; and we have seen that they are performed by the instrumentality of the Pneumogastric or proper Respiratory nerve (§ 718). A slight examina-

* These are not usually reckoned among the principal muscles concerned in regulating the voice; but that they are so, any one may convince himself by placing his finger just above the sternum, whilst he is sounding high notes; a strong feeling of muscular tension is then at once perceived.

tion of the recent Larynx is sufficient to make it evident, that, when once the borders of the rima glottidis are brought together by muscular action, the effect of strong aerial pressure on either side (whether produced by an expulsory blast from below, or by a strong inspiratory effort, occasioning a partial vacuum below, and consequently an increased pressure above), will be to force them into closer apposition.—In order to produce a Vocal sound, it is not sufficient to put the ligaments into a state of tension; they must also be brought nearer to each other. That the aperture of the glottis is greatly narrowed during the production of sounds, is easily made evident to oneself, by comparing the time occupied by an ordinary expiration, with that required for the passage of the same quantity of air during the sustenance of a vocal tone. Further, the size of the aperture is made to vary in accordance with the note which is being produced; of this, too, any one may convince himself, by comparing the times during which he can hold out a low and a high note; from which it will appear, that the aperture of the glottis is so much narrowed in producing a high note, as to permit a much less rapid passage of air than is allowed when a low one is sounded. This adjustment of the aperture to the tension of the vocal ligaments, is a necessary condition for the production of a clear and definite tone. It further appears that, in the narrowing of the glottis which is requisite to bring the vocal ligaments into the necessary approximation, the upper points of the Arytenoid cartilages are caused to approximate, not only by being made to rotate horizontally towards each other, but also by a degree of elevation; so that the inner faces of the vocal ligaments are brought into parallelism with each other,—a condition which may be experimentally shown to be necessary for their being thrown into sonorous vibration. The muscular movements concerned in the act of vocalization, appear to be called forth by the instrumentality of the fibres of the Spinal Accessory nerve which are contained in the Pneumogastric (§ 719.)

931. We have now to inquire what is the operation of the Vocal Ligaments in the production of sounds; and in order to comprehend this, it is necessary to advert to the conditions under which tones are produced by instruments of various descriptions having some analogy with the Larynx. These are chiefly of three kinds; strings, flute-pipes, and reeds or tongues.—The Vocal Ligaments were long ago compared by Ferrein to vibrating *strings;* and at first sight there might seem a considerable analogy, the sounds produced by both being elevated by increased tension. This resemblance disappears, however, on more accurate comparison; for it may be easily ascertained by experiment, that no string so short as the vocal ligaments could give a clear tone, at all to be compared in depth with that of the lowest notes of the human voice; and also, that the scale of changes produced by increased tension is fundamentally different. When the strings of the same length but of different tensions, are made the subject of comparison, it is found that the number of vibrations is in proportion to the square-roots of the extending forces. Thus, if a string extended by a given weight produce a certain note, a string extended by four times that weight will give a note in which the vibrations are twice as rapid; and this will be the octave of the other. If nine times the original weight be employed, the vibrations will be three times as rapid as those of the fundamental note, producing the twelfth above it.

Now by fixing the larynx in such a manner that the vocal ligaments can be extended by a known weight, Müller has ascertained that the sounds produced by a variation of the extending force do not follow the same ratio; and therefore the condition of these ligaments cannot be simply that of vibrating cords. Further, a cord of a certain length, which is adapted to give out a clear and distinct note, equal in depth to the lowest of the human voice, may be made by increased tension to produce all the superior notes, which, in stringed instruments, are ordinarily obtained by shortening the strings.* But it does not follow that a short string, which, with moderate tension, naturally produces a high note, should be able, by a diminution of the tension, to give out a deep one; for, although this might be theoretically possible, yet it cannot be accomplished in practice; since the vibrations become irregular on account of the diminished elasticity.† These considerations are in themselves sufficient to destroy the supposed analogy; and to prove that the Chordæ Vocales cannot be reduced to the same category with vibrating strings.—The next kind of instrument with which some analogy might be suspected, is the *flute-pipe*, in which the sound is produced by the vibration of an elastic column of air contained in the tube; and the pitch of the note is determined almost entirely by the length of the column, although slightly modified by its diameter, and by the nature of the embouchure or mouth from which it issues. This is exemplified in the German Flute, and in the English Flute or Flageolet; in both of which instruments, the acting length of the pipe is determined by the interval between the embouchure and the nearest of the side-apertures; by opening or closing which, therefore, a modification of the tone is produced. In the Organ, of which the greater number of pipes are constructed upon this plan, there is a distinct pipe for every note; and their length increases in a regular scale. It is, in fact, with flute-pipes as with strings,—that a diminution in length causes an increase in the number of vibrations, but in a simply inverse proportion; so that of two pipes, one being half the length of the other, the shorter will give a tone which is the octave above the other, the vibrations of its column of air being twice as rapid. Now there is nothing in the form or dimensions of the column of air between the larynx and the mouth, which can be conceived to render it at all capable of such vibrations as are required to produce the tones of the Human voice; though there is some doubt, whether it be not the agent in the musical tones of certain Birds. The length of an open pipe necessary to give the lowest G of the ordinary bass voice, is nearly six feet; and the conditions necessary to produce the higher notes from it, are by no means those which we find to exist in the process of modulating the human voice.—We now come to the third class of instruments, in which sound is produced by the vibration

* Thus in the Piano-forte, where there are strings for each note, a gradual shortening is seen from the lowest to the highest; and in the Violin the change of tone is produced by *stopping* the strings with the finger, so as to diminish their acting length.

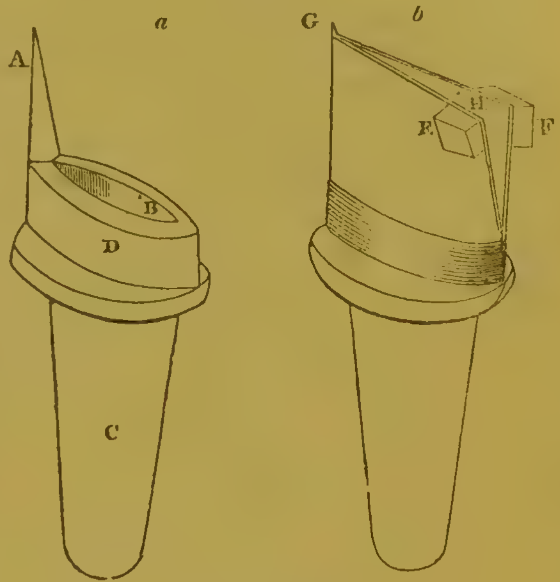
† Thus it would be impossible to produce good Bass notes on the strings of a Violin, by diminishing their tension; the length afforded by the Violoncello or Double Bass is requisite. The striking difference between the tone of the Bass strings in the Grand Piano-forte and the small upright Piccolo, is another exemplification of the same principle; being chiefly due to the length and tension of the former, as contrasted with the shortness and slackness of the latter.

of *reeds* or *tongues;* these may either possess elasticity in themselves, or be made elastic by tension. The 'free' reeds of the Eolina, Accordion, Seraphine, Harmonium, &c., are examples of instruments of this character, in which the lamina vibrates in a sort of frame that allows the air to pass out on all sides of it through a narrow channel, thus increasing the strength of the blast: whilst in the Hautboy, Bassoon, &c., and in Organ-pipes of similar construction, the reed covers an aperture at the side of one end of a pipe. In the former kind, the sound is produced by the vibration of the tongue alone, and is regulated entirely by its length and elasticity; whilst in the latter, its pitch is dependent upon this, conjointly with the length of the tube, the column of air contained in which is thrown into simultaneous vibration. Some interesting researches on the effect produced on the pitch of a sound given by a reed, through the union of it with a tube, have been made by M. W. Weber; and, as they are important in furnishing data by which the real nature of the vocal organ may be determined, their chief results will be here given. —I. The pitch of a reed may be lowered, but cannot be raised, by joining it to a tube. II. The sinking of the pitch of the reed thus produced, is at the utmost not more than an octave. III. The fundamental note of the reed thus lowered, may be raised again to its original pitch, by a further lengthening of the tube; and by a further increase is again lowered. IV. The length of tube, necessary to lower the pitch of the instrument to any given point, depends on the relation which exists between the frequency of the vibrations of the tongue of the reed, and those of the column of air in the tube, each taken separately.—From these data, and from those of the preceding paragraph, it follows that, if a wind-instrument can, by the prolongation of its tube, be made to yield tones of any depth in proportion to the length of the tube, it must be regarded as a flute-pipe; whilst if its pitch can only be lowered an octave or less (the embouchure remaining the same) by lengthening the tube, we may be certain that it is a reed instrument. The latter proves to be the case in regard to the Larynx.

932. It is evident from the foregoing considerations, that the action of the Larynx has more analogy to that of *reed* instruments, than it has to that either of vibrating *strings*, or of *flute pipes.* There would seem at first sight, to be a marked difference in character, between the vocal ligaments and the tongue of any reed instrument; but this difference is really by no means considerable. In a reed, elasticity is a property of the tongue itself, when fixed at one end, the other vibrating freely; but by a membranous lamina, fixed in the same manner, no tone would be produced. If such a lamina, however, be made elastic by a moderate degree of tension, and be fixed in such a manner as to be advantageously acted-on by a current of air, it will give a distinct tone. It is observed by Müller, that membranous tongues made elastic by tension, may have either of three different forms:— I. That of a band extended by a cord, and included between two firm plates, so that there is a cleft for the passage of air on each side of the tongue. II. The elastic membrane may be stretched over the half or any portion of the end of a short tube, the other part being occupied by a solid plate, between which and the elastic membrane a narrow fissure is left. III. Two elastic membranes may be extended across the mouth of a short tube, each covering a portion of the opening, and having a chink left open between

them.—This last is evidently the form most allied to the Human Glottis; but it may be made to approximate still more closely, by prolonging the membranes in a direction parallel to that of the current of air, so that not merely their edges, but their whole planes, shall be thrown into vibration. Upon this principle, a kind of *artificial glottis* has been constructed by Mr. Willis; the conditions of action and the effects of which, are so nearly allied to that of the real instrument, that the similar character of the two can scarcely be doubted. The following is his description of it. "Let a wooden pipe be prepared of the form of Fig. 149 *a*, having a foot, C, like that of an organ-pipe, and an upper opening, long and narrow, as at B, with a point, A, rising at one end of it. If a piece of leather, or still better, of sheet India-rubber, be doubled round this point, and secured by being bound round the pipe at D with strong thread, as in Fig. 149 *b*, it will give us an artificial glottis with its upper edges G H, which may be made to vibrate or not, at pleasure, by inclining the planes of the edges. A couple of pieces of cork, E, F, may be glued to the corners, to make them more manageable. From this machine, various notes may be obtained, by stretching the edges in the direction of their length G H; the notes rising in pitch with the increased tension, although the length of the vibrating edge is increased. It is true that a scale of notes equal in extent to that of the human voice cannot be obtained from edges of leather; but this scale is much greater in India-rubber than in leather; and the elasticity of them both is so much inferior to that of the vocal ligaments, that we may readily infer that the greater scale of the latter is due to its greater elastic powers." By other experimenters, the tissue forming the middle coat of the arteries has been used for this purpose, in the moist state, with great success; with this, the tissue of the vocal ligaments is nearly identical. It is worthy of remark that, in all such experiments, it is found that the two membranes may be thrown into vibration, when inclined *towards* each other in various degrees, or even when they are in parallel planes, and their edges only approximate; but that the least inclination *from* each other (which is the position the vocal ligaments have during the ordinary state of the glottis, § 930), completely prevents any sonorous vibrations from being produced.

Fig. 149.




Artificial Glottis.

933. The pitch of the note produced by membranous tongues, may be affected in several ways. Thus, an increase in the strength of the blast, which has little influence on metallic reeds, raises *their* pitch very considerably; and in this manner the note of a membranous reed may be raised by semitones, to as much as a fifth above the fundamental. The addition of a pipe has nearly the same effect on their pitch, as on that of metallic reeds; but it cannot easily be determined with the same precision. The

effect of the junction of a pipe with a double membranous tongue, is well shown in the Trumpet, Horn, and other instruments, which require the vibration of the lips, as well as a blast of air, for the production of their sound, having no reed of their own. By some, these instruments have been classed with Flute-pipes; but the conditions of their action are entirely different. The mouth-piece of the horn or trumpet is incapable of yielding any tone, when a current of air is merely blown through it; and the lips are necessary to convert it into a musical reed, being rendered tense by the contraction of their sphincter, partly antagonized by the slightly-dilating action of other muscles. The variation of the tension of the lips is effected by muscular effort; and several different notes may be produced with a pipe of the same length; but there is a certain length of the column of air, which is the one best adapted for each tone; and different instruments possess various contrivances for changing this. It has been recently ascertained, that the length of the pipe prefixed to the reed, has also a considerable influence on its tone, rendering it deeper in proportion as it is prolonged, down to nearly the octave of the fundamental note; but the pitch then suddenly rises again, as in the case of the tube placed beyond the reed. The researches of Müller, however, have not succeeded in establishing any very definite relation between the lengths of the two tubes, in regard to their influence on the pitch of the reed placed between them.

934. From the foregoing statements it appears, that the true theory of the Voice may now be considered as well established, in regard to this essential particular,—that the sound is the result of the vibrations of the vocal ligaments, which take place according to the same laws with those of metallic or other elastic tongues: and that the pitch of the notes is chiefly governed by the tension of these laminæ.* With respect, however to the mode and degree in which these tones are modified by the shape of the air-passages, both above and below the larynx, by the force of the blast, and by other concurrent circumstances, little is certainly known; but no doubt can be felt that these modifications are of great importance, when we observe the great amount of muscular action which takes place consentaneously with the production of vocal tones, and which seems designed to modify the length and tension of the various parts of the Vocal Tube, so that they may vibrate synchronously with the Vocal Cords. Thus, during the ascent of the voice from the deeper to the higher notes of the scale, we find the whole larynx undergoing an elevation towards the base of the cranium, the thyroid cartilage being drawn-up within the os-hyoides, so as even to press on the epiglottis; at the same time, the small space between the thyroid and cricoid cartilages,

* It is considered, however, by Mr. Bishop ("Cyclop. of Anat. and Physiol.," vol. iv. p. 1486), that the vocal apparatus combines the properties of a stretched cord, a membranous pipe with a column of air vibrating in it, and a reed; and is the perfect type, of which these instruments are only imperfect adaptations. The Author is unable, however, to deduce from Mr. Bishop's previous statements the grounds upon which he makes this assertion; and does not understand how any instrument *can* combine the actions of *strings* and of *tongues*, the laws of whose vibration are so different. That the column of air in the air-passages is thrown into vibration consentaneously with the production of sound by the vocal cords, and intensifies that sound by reciprocation, can scarcely be doubted; but the reasons previously given appear to the Author sufficient to disprove the notion, that this vibration is at all more essential to the production of the vocal tone, than it is in the reed-pipe of an organ.

or crico-thyroid chink, is closed by the depression of the front of the former upon the latter (§ 928); the velum palati is depressed and curved forwards; and the tonsils approach one another. The reverse of all these movements takes place during the descent of the voice. — A very important adjunct to the production of the higher notes has been pointed-out by Müller, as being afforded by the modification in the space included between the two sides of the thyroid cartilage, which is effected by the thyro-arytenoidei. He had experimentally ascertained, that the introduction of a hollow plug into the upper end of the pipe beneath his artificial larynx (and therefore just below the reed), by diminishing its aperture, produced a considerable elevation of the tone. The action may be imitated in the human larynx, when made the subject of experiment, by compressing the thyroid cartilage laterally; and in this manner, the natural voice could be made to extend through a range, that could otherwise be only reached by a falsetto. — The influence of the prefixed and superadded tubes, in modifying the tones produced by the Human larynx, has been found by Prof. Müller not to be at all comparable to that which they exercised over the artificial larynx; the reason of which difference does not seem very apparent. It appears, however, that there is a certain length of the prefixed tube—as there is a certain distance of the vibrating laminæ, and a certain length or form of the tube above, — which is most favourable to the production of each note; and the downward movement of the whole vocal organ, which takes place when we are sounding deep notes, and its rise during the elevation of the tones, have been supposed to have the purpose of making this adjustment in the length of the trachea; but this requires the supposition, that the real length of the trachea is shortened whilst it appears extended, — for which there seems no foundation. It is considered by Mr. Wheatstone, that the column of air in the trachea may divide itself into 'harmonic lengths,' and may produce a *reciprocation* of the tone given by the vocal ligaments (§ 899); and in this manner he considers that the falsetto notes are to be explained. It may be added, that the partial closing of the epiglottis seems to assist in the production of deep notes, just as the partial covering of the top of a short pipe fixed to a reed will lower its tone; and that something of this kind takes place during natural vocalisation, would appear from the retraction and depression of the tongue, which accompany the lowering of the front of the head, when the very lowest notes are being sounded. The experiments of Savart have shown, that a cavity which only responds to a shrill note, when its walls are firm and dry, may be made to afford a great variety of lower tones when its walls are moistened and relaxed in various degrees. This observation may probably be applied also to the trachea.

935. The *falsetto* is a peculiar modification of the voice, differing from the 'chest voice,' not merely in the higher pitch of its notes, but also in their quality; its tones being less reedy, and more like the 'harmonic notes' of stringed and winged instruments. In some individuals, the chest-voice passes by imperceptible gradations into the falsetto, whilst in others the transition is abrupt; and some persons can sound the same notes in the two different registers, these notes forming the upper part of the scale of the chest-voice, and the lower part of the falsetto. Thus a gentleman of the Author's acquaintance has a bass voice of a harsh reedy

character, ranging from the D below the bass cleff to the D above it (two octaves); whilst his falsetto, which is remarkable for its clearness and smoothness, ranges from the A on the highest line of the bass cleff to the E in the highest space of the treble cleff. Thus there are five notes common to the two registers, and the entire voice ranges through more than three octaves; but from want of a gradual passage from one to the other, this gentleman can only sing bass parts with his chest-voice, or alto parts with his falsetto, the tenor scale extending above the range of one, and below that of the other.—With regard to the theory of the production of the falsetto voice, there has been considerable difference of opinion amongst Physiologists; and it cannot be regarded as fully determined. By Magendie and Mayo it was maintained that these tones are produced by the vibration of the vocal cords along only half their length, the rima glottidis being partly closed; and this explanation is consistent with the fact, that a far smaller quantity of air is required for sustaining a falsetto note, than for a note of the ordinary register, even though they should be of the same pitch. By Müller, again, it is asserted that in the production of the falsetto notes merely the thin border of the glottis vibrates, so that the fissure remains distinctly visible; whilst in the production of the ordinary vocal tones, the whole breadth of the vocal ligaments is thrown into strong vibrations, which traverse a wider space, so that a confused motion is seen in the lips of the glottis, rendering its fissure indefinite. It is not impossible that both these doctrines are correct; and that, in the production of falsetto notes the vocal ligaments are in contact with each other for part of their length, and that only their thin edges are in vibration in the remainder. It has been pointed-out by Mr. Bishop (loc. cit.), that at the moment of transition from the 'chest-voice' to the 'falsetto-voice,' the crico-thyroid chink, which was closed during the production of the highest note of the former, suddenly opens on the production of the lowest note of the latter; thus indicating that the Vocal Cords are *relaxed* in the passage from the one to the other, as must be the case, if, for the production of the same note, they be only put in vibration along a part of their length; so that it would not seem improbable, that the cause of those differences in the mode of transition which have been already noticed, lies in the difference in the proportional amount of the vocal cords which is thus thrown out of use by the partial approximation of the two lips of the rima glottidis. It is further remarked by Mr. Bishop, that, in the passage from the chest to the falsetto-voice, the larynx descends from its previously-elevated position, and gradually rises again with the ascending scale of falsetto notes; and he mentions a case of *double falsetto*, in which a third register existed, and in which the relaxation of the Vocal cords and the descent of the larynx were observed at its commencement, as at the commencement of the second or ordinary falsetto register.—An entirely different theory of the falsetto has been given, however, by MM. Pétrequin and Diday;* who consider that the falsetto notes are not produced by the vibration of the vocal cords, but are really 'flute-notes,' formed by the vibrations of the column of air to which the rima-glottidis then serves as the embouchure. This view harmonizes well with some of the phenomena of the

* "Gazette Médicale," 1844.

falsetto voice; but it is open to the objections already stated in regard to the flute-theory generally. It may be added that some have attempted to show that the falsetto depends upon a peculiar action of the parts above the larynx; but for this doctrine there is no foundation whatever.

936. The various muscular actions, which are employed in the production and regulation of the voice, are called-forth by an impulse which has been shown (§ 751) to be really *automatic* in its operation, and to be completely under the influence of guiding sensations, although usually originating in a Volitional determination, or giving expression to Emotions or simply to Ideas. This, however, has been proved to be true of *all* Volitional movements; so that the production of vocal tones constitutes no real exception. It may be safely affirmed, that the simple utterance of sounds is in itself an Instinctive action; although the combination of these, whether into music or articulate language, is a matter of acquirement, which is much more readily made by some individuals than by others. No definite tone can be produced by a Voluntary effort, unless that tone be present to the Consciousness during an interval—however momentary,—either as immediately produced by an act of Sensation, recalled by an act of Conception, or anticipated by an effort of the Imagination. When thus present, the Will can enable the muscles to assume the condition requisite to produce it; but under no other circumstances does this happen, except through the particular mode of discipline by which the congenitally deaf may be trained to speak. Such persons are debarred from learning the use of Voice in the ordinary manner; for the necessary guidance cannot be afforded, either through sensations of the present or conceptions of the past, and the imagination is entirely destitute of power to suggest that which has been in no shape experienced. But they may be taught to acquire an imperfect speech, by causing them to imitate particular muscular movements, which they may be made to see; being guided in the imitation of those movements, in the first place by watching their own performance of them in a looking-glass, and afterwards by attending to the muscular sensations which accompany them. Many instances, indeed, are on record, in which persons entirely deaf were enabled to carry-on a conversation in the regular way; judging of what was said by the movements of the lips and tongue, which they had learned to connect with particular syllables; and regulating their own voices in reply, by their voluntary power, guided in its exercise by their muscular sensations.*

[In the foregoing account of the Physiology of Voice, the Author has been chiefly guided by the excellent paper by Mr. Willis in the "Transactions of the Cambridge Philosophical Society," vol. iv.; and by the elaborate investigations of Müller and his coadjutors, as detailed in the Fourth Book of his Physiology. Mr. Bishop's account of the Physiology of Voice, in the Fourth Volume of the "Cyclopædia of Anatomy and Physiology" may also be advantageously consulted.]

* See Dr. Johnstone "On Sensation," p. 128.

## 2.—*Of Articulate Sounds.*

937. The larynx, as now described, is capable of producing those *tones* of which Voice fundamentally consists, and the sequence of which becomes Music: but *Speech* consists in the modification of the laryngeal tones, by other organs intervening between the Glottis and the Os externum, so as to produce those *articulate sounds* of which language is formed. It cannot be questioned that Music has its language; and that it is susceptible of expressing the emotional states of the mind, among those at least who have been accustomed to associate these with its varied modes, to even a higher degree than articulate speech. But it is incapable of addressing the intellect, by conveying definite ideas of objects, properties, actions, &c., in any other way than by a kind of imitation, which may be compared to the signs used in hieroglyphic writing. These ideas it is the peculiar province of articulate language to convey; and we find that the vocal organ is adapted to form a large number of simple sounds, which may be readily combined into groups, forming words. The number of combinations which can be thus produced, is so inexhaustible, that every language has its own peculiar series; no difficulty being found in forming new ones to express new ideas. There is considerable diversity in different languages, even with regard to the use of the simplest of these combinations; some of them are more easy of formation than others, and these accordingly enter into the composition of all languages; whilst of the more difficult ones, some are employed in one language, some in another, — no one language possessing them all. Without entering into any detailed account of the mechanism required to produce each of these simple sounds, a few general considerations will be offered in regard to the classification of them; and the peculiar defect of articulation, termed *Stammering*, will be briefly treated-of.

938. Vocal sounds are divided into Vowels and Consonants; and the distinctive characters of these are usually considered to be, that the Vowels are produced by the Voice alone, whilst the sound of the Consonant is formed by some kind of interruption to the voice, so that they cannot be properly expressed, unless conjoined with a vowel. The distinction may be more correctly laid down, however, in this manner:—the Vowel sounds are continuous tones, modified by the form of the aperture through which they pass out; whilst in sounding Consonants, the breath suffers a more or less complete interruption, in its passage through parts anterior to the larynx. Hence the really simple Vowel sounds are capable of prolongation during any time that the breath can sustain them; this is not the case, however, with the *real* Diphthongal sounds (of which it will presently appear that the English *i* is one); whilst it is true of some Consonants. It seems to have been forgotten by many of those who have written upon this subject, that the laryngeal voice is not essential to the formation of either vowels or consonants; for all may be sounded in a whisper. It is very evident, therefore, that the larynx is not primarily concerned in their production; and this has been fully established by the following experiment. A flexible tube was introduced by M. Deleau through his nostril into the pharynx, and air was impelled by it into the fauces; then, closing the larynx, he threw the fauces into the different positions requisite for

producing articulate sounds, when the air impelled through the tube became an audible whisper. The experiment was repeated, with this variation,—that laryngeal sounds were allowed to pass into the fauces; and each articulated letter was then heard double, in a proper voice and in a whisper.

939. That the Vowels are produced by simple modifications in the form of the external passages, is easily proved, both by observation and by imitative experiment. When the mouth is opened wide, the tongue depressed, and the velum palati elevated, so as to give the freest possible exit to the voice, the vowel *a* in its broadest form (as in *ah*) is sounded.* On the other hand, if the oral aperture be contracted, the tongue being still depressed, the sound *oo* (the continental *u*) is produced. If attention be paid to the state of the buccal cavity, during the pronunciation of the different vowel sounds, it will be found to undergo a great variety of modifications, arising from varieties of position of the tongue, the cheeks, the lips, and velum palati. The position of the tongue is, indeed, one of the primary conditions of the variation of the sound; for it may be easily ascertained that, by peculiar inflexions of this organ, a great diversity of vowel sounds may be produced, the other parts remaining the same. Still there is a certain position of all the parts, which is most favourable to the formation of each of these sounds; but this could not be expressed without a lengthened description. The following table, slightly altered from that of Kempelen, expresses the relative dimensions of the buccal *cavity* and of the oral *orifice*, for some of the principal of these; the number 5 expressing the largest size, and the others in like proportion:—

| *Vowel.* | *Sound.* | *Size of oral opening.* | *Size of buccal cavity.* |
|---|---|---|---|
| a | as in *ah* | 5 | 5 |
| a | as in *name* | 4 | 2 |
| e | as in *theme* | 3 | 1 |
| o | as in *cold* | 2 | 4 |
| oo | as in *cool* | 1 | 5 |

These are the sounds of the five vowels, *a*, *e*, *i*, *o*, *u*, in most Continental languages; and it cannot but be admitted, that the arrangement is a much more natural one than that of our own vowel series. The English *a* has three distinct sounds capable of prolongation;†—the true broad *a* of *ah*, slightly modified in *far;* the *a* of *fate*, corresponding to the *e* of French; and the *a* of *fall*, which should be really represented by *au*. This last is a simple sound, though commonly reckoned as a diphthong. In Kempelen's scale, the oral orifice required to produce it would be about 3, and the size of the buccal cavity 4.‡ On the other hand, the sound of the English

* This sound of the vowel *a* is scarcely used in our language, though very common in most of the continental tongues; the nearest approach to it in English is the *a* in *far;* but this is a very perceptible modification, tending towards *au*.

† The *short* vowel sounds, as *a* in fat, *e* in met, *o* in pot, &c., are not capable of prolongation.

‡ The mode of making a determination of this kind may here be given, for the sake of example. If the broad *a* be sounded, the mouth and fauces being opened wide, and we contract the oral orifice by degrees, at the same time slightly elevating the point of the tongue, we gradually come to the sound of *au;* by still further contracting the orifice, and again depressing the tongue, we form *oo*. On the other hand, in sounding *e*, the tongue is raised nearly to the roof of the mouth; if it be depressed, without the position of the lips being altered, *au* is given.

*i* cannot, like that of a true vowel, be prolonged *ad libitum;* it is in fact a sort of diphthong, resulting from the transition from a peculiar indefinite murmur to the sound of *e*, which takes its place when we attempt to continue it. The sound *oy* or *oi*, as in *oil*, is a good example of the true diphthong; being produced by the transition from *au* to *e*. In the same manner, the diphthong *ou*, which is the same with *ow* in owl, is produced in the rapid transition from the broad *a* of *ah*, to the *oo* of cool.—Much discussion has taken place as to the true character of *y*, when it commences a word, as in yet, yawl, &c.; some having maintained that it is a consonant (for the very unsatisfactory reason, that we are in the habit of employing *a* rather than *an*, when we desire to prefix the indefinite article to such words), whilst others regard it as a peculiar vowel. A slight attention to the position of the vocal organs during its pronunciation, makes it very clear, that its sound in such words really corresponds with that of the long (English) *e;* the pronunciation of the word yawl being the same as that of ēaul, when the first sound is not prolonged, but rapidly transformed into the second. The sound of the letter *w*, moreover, is really of the vowel character, being formed in the rapid transition from *oo* to the succeeding vowel; thus *wall* might be spelt *ōōall.* Many similar difficulties might be removed, and the conformity between spoken and written language might be greatly increased (so as to render far more easy the acquirement of the former from the latter), by due attention to the state of the vocal organs in the production of the simple sounds.

940. It is not very difficult to produce a tolerably good artificial imitation of the Vowel sounds. This was accomplished by Kempelen, by means of an India-rubber ball, with an orifice at each end, of which the lower one was attached to a reed: by modifying the form of the ball, the different vowels could be sounded during the action of the reed. He also employed a short funnel-like tube, and obtained the different sounds by covering its wide opening to a greater or less extent. This last experiment has been repeated by Mr. Willis; who has also found that the vowel sounds might be imitated, by drawing out a long straight tube from the reed. In this experiment he arrived at a curious result:—with a tube of a certain length, the series of vowels, *i, e, a, o, u*, was obtained, by gradually drawing it out; but, if the length was increased to a certain point, a further gradual increase would produce the same sequence in an inverted order, *u, o, a, e, i;* a still further increase would produce a return to the first scale, and so on. When the pitch of the reed was high, and the pipe short, it was found that the vowels *o* and *u* could not be distinctly formed, —the proper tone being injured by the elongation of the pipe necessary to produce them; and this, Mr. Willis remarks, is exactly the case in the Human voice, most singers being unable to pronounce *u* and *o* upon their highest notes.

941. The most natural primary division of the Consonants, is into those which require a total stoppage of the breath at the moment previous to their being pronounced, and which, therefore, cannot be prolonged; and those in pronouncing which the interruption is partial, and which can, like the vowel sounds, be prolonged *ad libitum.* The former have received the designation of *explosive;* and the latter of *continuous.*—In pronouncing the *explosive* consonants, the posterior nares are completely closed, so that the exit of air through the nose is altogether prevented; and the

urrent may be checked in the mouth in three ways, by the approximation of the lips,—by the approximation of the point of the tongue to the ront of the palate,—and by the approximation of the middle of the tongue o the arch of the palate. In the first of these modes, we pronounce the etters *b*, and *p;* in the second, *d*, and *t;* in the third, the hard *g*, and *k*. The difference between *b*, *d*, and *g*, on the one hand, and *p*, *t*, and *k*,* on he other, seems to depend on this;—that in the former group the pproximating surfaces are larger, and the breath is sent through them nore strongly at the moment of opening, than in the latter.—The *continuous* consonants may be again subdivided, according to the degree of reedom with which the air is allowed to make its exit, and the compresion which it consequently experiences. I. The first class includes those, n which no passage of air takes place through the nose, and in which the arts of the mouth that produce the sound are nearly approximated ogether, so that the compression is considerable. This is the case with and *f*, which are produced by approximating the upper incisors to the ower lip; and which stand in nearly the same relation to each other, as hat which exists between *d* and *t*, or *b* and *p*. The sibilant sounds, *z*, nd *s*, also stand in a similar relation to each other; they are produced y the passage of air between the point of the tongue and the front of the alate, the teeth being at the same time nearly closed. The simple sound *h* is formed, by narrowing the channel between the dorsum of the tongue nd the palate; the former being elevated towards the latter, through a onsiderable part of its length. If, in sounding *s*, we raise the point of he tongue a very little, so as to touch the palate, the sound of *t* is volved; and in the same manner *d* is produced from *z*. This class also ncludes the *th;* which, being a perfectly simple sound, ought to be xpressed by a single letter, as in Greek, instead of by two, whose combination does not really produce anything like it. For producing this ound, the point of the tongue is applied to the back of the incisors, or o the front of the palate, as in sounding *t;*† but, whilst there is complete ontact of the tip, the air is allowed to pass out around it. II. In the econd class of continuous consonants, including the letters *m*, *n*, *l*, and *r*, he nostrils are not closed; and the air thus undergoes very little compression, even though the passage of air through the oral cavity is almost r completely checked. In pronouncing *m* and *n*, the breath passes hrough the nose alone: and the difference of the sound of these two etters must be due to the variation in the form of the cavity of the nouth, which acts by resonance. The letter *m* is a labial, like *b;* and he only difference between the two is, that in the former the nasal passage s open, whilst the mouth remains closed; whilst in the latter, the nose is ntirely closed, and the sound is formed at the moment of opening the nouth. The same correspondence exists between *n* and *t*, or *n* and *g* (the articular part of the tongue approximated to the palate not being of nuch consequence in the pronunciation of *n*); and hence it is that the ransition from *n* to *t*, or from *n* to *g*, is so easy, that the combinations *t* and *ng* are found abundantly in most languages. The sound of *l* is roduced by bringing the tip of the tongue into contact with the palate,

* For the sake of proper comparison, this letter should be sounded not as *kay* but as *key*.

† Hence it is easy to understand the substitution of *t* or *d*, for the English *th*, by reigners.

and allowing the air to escape around it, at the same time that a vocal tone is generated in the larynx; it differs, therefore, from *th* in the position at which the obstruction is interposed, as well as in the slight degree of compression of the air which it involves. The sound of the letter *r* depends on an absolute vibration of the point of the tongue, in a narrow current of air forced between the tongue itself and the palate. III. The sounds of the third class are scarcely to be termed consonants, since they are merely *aspirations* caused by an increased force of breath. These are *h*, and the guttural *ch** of most foreign languages (the Greek χ). The first is a simple aspiration; the second an aspiration modified by the elevation of the tongue, causing a slight obstruction to the passage of air, and an increased resonance in the back of the mouth. This sound would become either *g* or *k*, if the tongue, whilst it is being produced, were carried up to touch the palate.†

942. These distinctions come to be of much importance, when we apply ourselves to the treatment of defects of articulation. Great as is the number of muscles employed in the production of definite vocal sounds, the number is much greater for those of articulate language; and the varieties of combination which we are continually forming unconsciously to ourselves, would not be suspected, without a minute analysis of the separate actions. Thus, in uttering the explosive sounds, we check the passage of air through the posterior nares, in the very act of articulating the letter; and yet this important movement commonly passes unobserved.—We must regard the power of forming the several articulate sounds which have been adverted to, and their simple combinations, as so far resulting from intuition, that it can in general be more readily acquired by early practice than other actions of the same complexity; but we find that among different Races of Men, there exist tendencies to the production of different sounds, which, though doubtless influenced in great degree by early habit (since we find that children, when first learning to speak, form their habits of vocalization in great degree in accordance with the examples amidst which they are placed), are certainly also dependent in part upon congenital constitution, as we often see in the case of children among ourselves, who grow up with certain peculiarities of pronunciation of which they do not seem able to divest themselves. It is, however, in the want of power to *combine* the different muscular actions concerned in vocalization, that the defect termed *Stammering* essentially consists.

943. Many theories regarding the nature of Stammering have been proposed; and there can be little doubt that the impediment may be attributed to a great variety of exciting causes. A disordered action of the nervous centres must, however, be regarded as the proximate cause; though this may be (to use the language of Dr. M. Hall) either of *centric* or of *excentric* origin,—that is it may result from a morbid condition of the ganglionic centre, or from an abnormal impression conveyed through its afferent nerves. When of centric origin (and this is probably the most general case), the phenomena of Stammering and Chorea have a close analogy to each other; in fact stammering is frequently one of the modes

* The English *ch* is merely a combination of *t* with *sh*; thus *chime* might be spelt *tshime*.

† The general classification proposed by Dr. M. Hall has been here adopted, with some modification as to the details.

in which the disordered condition of the nervous system in Chorea manifests itself.—It is in the pronunciation of the Consonants of the *explosive* class, that the stammerer experiences the greatest difficulty. The total interruption to the breath which they occasion, frequently becomes quite spasmodic; and the whole frame is thrown into the most distressing semi-convulsive movement, until relieved by expiration.* In the pronunciation of the *continuous* Consonants of the first class, the stammerer usually prolongs them, by a spasmodic continuance of the same action; and there is, in consequence, an impeded, but not a suspended respiration. The same is the case with the *l* and *r* in the second class. In pronouncing the *m* and *n*, on the other hand, as well as the aspirates and vowels, it is sometimes observed that the stammerer prolongs the sound, by a full and exhausting expiration. In all these cases, then, it seems as if the muscular sense, resulting from each particular combination of actions, became the stimulus to the involuntary prolongation of that action. It is possible that the defect may result, in some instances, from malformation of the parts about the fauces, producing an abnormal stimulus of this kind in some particular positions of the organ; and such cases *may be* really benefited by an operation for the removal of these parts. But the effect of such an operation is certainly exerted in most cases through the *mind* of the patient; the expectation of benefit from it tending to improve his command over the muscles of vocalization, which Emotional excitement always impairs; and the improvement is usually proportional to the confidence which he has been led to feel in the result. The slightest disturbance of the feelings is sufficient in most Stammerers to induce a complete perturbation of the vocal powers; the very fear that stammering will occur, particularly under circumstances which render it peculiarly annoying, is often sufficient to bring it on in a predisposed subject; and the tendency to consensual imitation sometimes occasions stammering, in individuals (especially children) who never show the slightest tendency to it except when they witness the difficulty in others.

944. The method proposed by Dr. Arnott for the prevention of Stammering, consists in the connection of all the words by a vocal intonation, in such a manner, that there shall never be an entire stoppage of the breath. It is justly remarked by Müller, however, that this plan may afford some benefit, but cannot do everything; since the main impediment occurs in the middle of words themselves. One important remedial means, on which too much stress cannot be laid, is to study carefully the mechanism of the articulation of the difficult letters, and to practise their pronunciation repeatedly, slowly, and analytically. The patient would at first do well to practise sentences from which the explosive consonants are omitted; his chief difficulty, arising from the spasmodic suspension of the expiratory movement, being thus avoided. Having mastered these, he may pass-on to others, in which the difficult letters are sparingly introduced; and may finally accustom himself to the use of ordinary language. One of the chief points to be aimed-at, is to make the patient feel that he *has* command over his muscles of articulation; and this is the best done, by gradually leading him from

* By Dr. Arnott this interruption is represented as taking place in the larynx; that such is not usually the case, the Author believes that a little attention to the ordinary phenomena of voice will satisfactorily prove.

that which he finds he *can* do, to that which he fears he cannot. The fact that stammering people are able to *sing* their words better than to *speak* them, has been usually explained on the supposition that, in singing, the glottis is kept open, so that there is less liability to spasmodic action; if, however, as here maintained, the spasmodic action is not in the larynx, but in the velum palati and the muscles of articulation, the difference must be due to the direction of the attention rather to the muscles of the larynx than to those of the mouth.—One of the most important objects to be aimed-at in the treatment of stammering, consists in the prevention of all Emotional disturbance in connection with the act of Speech; and this requires the exercise of the Voluntary power over the direction of the thoughts, in the following modes:—1. To *reduce* mental emotion, by a daily, hourly, habit of abstracting the mind from the subject of stammering, both while speaking, and at other times. 2. To *avoid exciting* mental emotion by attempting unnecessarily to read or speak, when the individual is conscious that he shall not be able to perform these actions without great distress. 3. To *elude* mental emotion, by taking advantage of any little artifice to escape from stammering, so long as the artifice continues to be a successful one.—Much may frequently be done, also, by constitutional treatment, adapted to improve the general condition of the nervous system.*

## CHAPTER XVIII.

### INFLUENCE OF THE NERVOUS SYSTEM ON THE ORGANIC FUNCTIONS.

945. Of the modes in which the Nervous System influences the Organic Functions, a great part have been already considered: for it has been shown to be concerned in providing the conditions, either immediate or remote, under which alone these functions can be performed; so that, when its activity ceases, they cannot be much longer maintained. But the influence of the Nervous System is not alone exerted upon the motor or contractile tissues of the body; for there is good evidence that it has a direct operation upon the molecular changes which constitute the functions of Nutrition, Secretion, &c.; and it is quite conformable to the general views formerly expressed (CHAP. III.), respecting the relations of the different kinds of Vital Force, that the *nerve-force*, which is itself generated by cell-development, should in its turn be able to modify other processes of cell-development (§ 111). And this view may be admitted to its fullest extent, without our thereby being led to regard the processes in question as *dependent* upon Nervous agency,—a doctrine for which there seems no valid foundation, since they go-on with the greatest rapidity and energy in the Vegetable kingdom, in which nothing approaching to a Nervous System exists; whilst in the Animal kingdom they

* See on the subject of "Stammering and its Treatment," a useful pamphlet under this title, by Bacc. Med. Oxon., 1850; and Mr. Bishop's treatise "On Articulate Sounds, and on the Causes and Cure of Impediments of Speech."

take place with equal vigour, long before the least vestige of it appears. We shall see that in the earliest condition of fœtal life, the germ consists but of a congeries of cells, which have all originated in a single one (§ 993); and from this mass, the several tissues and organs are successively generated by the processes of histological and morphological transformation,—one set of cells being converted into muscular tissue, another into nervous tissue, another into mucous membrane, and so on. Now since this is the case, it is evident that all these processes of development must take place, in virtue of the inherent properties of the primitive substance itself; since no nervous influence can be supposed to operate, before nerves are called into existence. Throughout the Animal body, it may be observed that, the more Vegetative the nature of any function, the less is it connected with the Nervous System; and all the experiments which have been regarded as proving that the Organic functions are *dependent upon* Nervous influence, are really explicable, fully as well, upon the supposition that they are capable of being *affected by* it, either in the way of excitement or retardation. (See § 447). Moreover, there is abundant evidence that Secretion may take place after the death of the general system, through the persistence of certain molecular changes whose essential conditions are not immediately altered; thus Mr. T. Bell mentions that, in dissecting the poison-apparatus of a Rattle-snake which had been dead for some hours, the poison continued to be secreted so fast as to require being occasionally dried-off. This is precisely what might have been anticipated, from the independent power of growth in the secreting cells; and other acts of Nutrition are recorded to have occurred under similar circumstances. In such a case, the Animal body is reduced to the condition of a Plant; since the influence of the Nervous system must then be entirely extinct. Upon those who maintain that Nervous agency is a condition *essential* to those molecular actions of which Nutrition and Secretion consist, it is incumbent, therefore, to offer some more unexceptionable proof of their position than has yet been given; since their doctrine is opposed by so many considerations of great weight.

946. That many of the Organic Functions, however, are directly influenced by the Nervous System, is a matter which does not admit of dispute; and this influence, exerted sometimes in exciting, sometimes in checking, and sometimes in otherwise modifying them, may well be compared to that which the hand and heel of the rider have upon his horse, or which the engine-driver exerts over a locomotive. It is most remarkably manifested in the result of severe injury of the Nervous centres, such as concussion of the Brain or of the Solar plexus (§ 321); for this does not merely bring about a suspension of the respiratory and other movements which minister to the Organic functions, hence inducing a gradual stagnation of the latter; but occasions a sudden and complete cessation of the whole train of action, which cannot be attributed to any other cause than a *positive* depressing influence of some kind, propagated through the Nervous System. In such cases, even the vitality of the Blood is often affected; the usual coagulation not taking place after death, so long, at least, as the blood remains within the vessels. A similar general depression may result from Mental Emotion, operating through the same channel; but this more commonly has rather a local action, or operates more gradually (§ 797).

947. The influence of the Nervous System is often especially exerted, in giving temporary excitement to a Secreting process, which need not be kept in constant activity, or of which circumstances may occasionally require an increase. This is the case, for example, in regard to the secretions connected with the process of digestion,— the Saliva, Gastric fluid, Bile, Pancreatic fluid, &c.; all of these being excited by the contact of the substances on which they act, with the surfaces on which their respective ducts open. The secretion of Milk, again, in a nursing female, may be excited by irritation of the nipple; and the determination of blood to the Mammæ during pregnancy arises from an increased action in the part, which is probably excited sympathetically by the changes occurring in the Uterus; and for this kind of communication, the Sympathetic System seems to afford the readiest channel, since the organs in question are for the most part supplied by it. There is an apparent exception, however, in the case of the Salivary and Lachrymal glands, which are supplied by the 5th Pair: but this nerve contains so many organic filaments, and is so intimately connected with the Sympathetic, as evidently to supply (in the head) the place of a separate ganglionic system. It is by Nervous influence, that the mucous secretion covering the membranes is caused to be regularly formed for their protection; for it is shown by pathological facts, that, when this influence is interrupted, and the secretion is no longer supplied, the membrane, losing its protection, is irritated by the air or the fluids with which it may be in contact, and passes into an inflammatory condition. This is partly the explanation of the fact, which has been well ascertained, that the eye is liable to suppurate when the 5th pair has been divided; and that the mucous membrane of the bladder becomes diseased in paraplegia.

948. The influence of particular conditions of the Mind, in exciting various Secretions, is a matter of daily experience. The flow of Saliva, for example, is stimulated by the idea of food, especially that of a savoury character. The Lachrymal secretion, again, which is continually being formed to a small extent for the purpose of bathing the surface of the eye, is poured-out in great abundance under the moderate excitement of the emotions, either of joy, tenderness, or grief. It is checked, however, by violent emotions; hence in intense grief, the tears do not flow; and it is a well-known proof of moderated sorrow when the gush takes place, this very act affording a further relief (§ 797). Violent emotion may also suspend the Salivary secretion; as is shown by the well-known test, often resorted-to in India, for the discovery of a thief amongst the servants of a family,—that of compelling all the parties to hold a certain quantity of rice in the mouth during a few minutes,—the offender being generally distinguished by the comparative dryness of his mouthful at the end of the experiment. The influence of the emotion of love-of-offspring, in increasing the secretion of Milk, is well known. The formation of this fluid is continually going on during the period of lactation; but it is greatly increased by the sight of the infant, or even by the thought of him, especially when associated with the idea of suckling; this gives rise to the sudden rush of blood to the gland, which is known by nurses as the *draught*, and which occasions a greatly-increased secretion. The strong desire to furnish milk, together with the irritation of the gland through the nipple, have often been effectual in producing the secretion in girls and old women, and even in

men (§ 1021, *c*, *d*). The quantity of the Gastric secretion is increased by exhilaration, at least if we may judge from the increase of the digestive powers under such circumstances. Freedom from mental anxiety favours the secretion of Fat; whilst continual solicitude effectually checks the disposition. It has been stated that total despair has an equal tendency with absence of care, to produce this effect; persons left long to pine in condemned cells, without a shadow of hope, frequently becoming remarkably fat, in spite of their slender fare.* The odoriferous secretion of the Skin, which is much more powerful in some individuals than in others, is increased under the influence of certain mental emotions (as fear or bashfulness), and commonly also by sexual desire. The Sexual secretions themselves are strongly influenced by the condition of the mind. When it is frequently and strongly directed towards objects of passion, these secretions are increased in amount, to a degree which may cause them to be a very injurious drain on the powers of the system. On the other hand, the active employment of the mental powers on other objects, has a tendency to render less active, or even to check altogether, the processes by which they are elaborated.†

* Fletcher's "Rudiments of Physiology," Part II., *b*, p. 11.

† This is a simple physiological fact, but of high moral application. The Author would say to those of his younger readers, who urge the wants of Nature as an excuse for the illicit gratification of the sexual passion, "Try the effects of close mental application to some of those ennobling pursuits, to which your profession introduces you, in combination with vigorous bodily exercise (for the effects of which see § 771), before you assert that the appetite is unrestrainable, and act upon that assertion." Nothing tends so much to increase the desire, as the continual direction of the mind towards the objects of its gratification. The following observations, which the Author believes to be strictly correct, are extracted from a valuable little work (anonymous) intitled, "Be not deceived," addressed to Young Men; they are directed to those who maintain that, the married state being natural to Man, illicit intercourse is necessary for those who are prevented by circumstances from otherwise gratifying the sexual passion. "When the appetite is naturally indulged, that is, in marriage, the necessary energy is supplied by the nervous stimulus of its natural accompaniment of love before referred-to, which prevents the injury that would otherwise arise from the increased expenditure of animal power: and in like manner also, the function being in itself grateful, this personal attachment performs the further necessary office of preventing immoderate indulgence, by dividing the attention, through the numerous other sources of sympathy and enjoyment which it simultaneously opens to the mind. But, when the appetite is irregularly indulged, that is in fornication, for want of the healthful vigour of true love, its energies become exhausted; and from the want of the numerous other sympathetic sources of enjoyment in true love, in similar thoughts, common pursuits, and above all in common holy hopes, the mere gross animal gratification of lust is resorted to with unnatural frequency, and thus its powers become still further exhausted, and, therefore, still more unsatisfying, while, at the same time, a habit is thus created, and these jointly cause an increased craving; and the still greater deficiency in the satisfaction experienced in its indulgence further, continually, ever in a circle, increases—the habit, demand, indulgence, consequent exhaustion, diminished satisfaction, and again demand,—till the mind and body alike become disorganised." Such considerations as these may, to some persons, appear misplaced in a Physiological Treatise—yet the Author feels sure that, by his well-judging readers, he will not be blamed for adverting to this subject, or for the introduction of the above quotation from a writer, of whom he has no personal knowledge, but whose object must be confessed by all to be laudable. There seems to be something in the process of training young men for the Medical Profession, which encourages in them a laxity of thought and expression on these matters, that generally ends in a laxity of principle and of action. It might have been expected that those who are so continually witnessing the melancholy consequences of the violation of the Divine law in this particular, would be the last to break it themselves: but this is unfortunately very far from being the case. The Author regrets to be obliged further to remark, that some works which have issued from the Medical press, contain much that is calculated to excite, rather than to repress, the propensity; and that the advice sometimes given by practitioners to their patients, is immoral as well as unscientific.

949. No secretion so evidently exhibits the influence of the depressing Emotions, as that of the Mammæ; but this may be partly due to the fact, that the digestive system of the Infant is a more delicate apparatus for testing the qualities of that secretion, than any which the Chemist can devise; affording proof, by disorder of its function, of changes in the character of the Milk, which no examination of its physical properties could detect. The following remarks on this subject are abridged from Sir A. Cooper's valuable work on the Breast. "The secretion of milk proceeds best in a *tranquil state of mind*, and with a cheerful temper; then the milk is regularly abundant, and agrees well with the child. On the contrary, a *fretful temper* lessens the quantity of milk, makes it thin and serous, and causes it to disturb the child's bowels, producing intestinal fever and much griping. *Fits of anger* produce a very irritating milk, followed by griping in the infant, with green stools. *Grief* has a great influence on lactation, and consequently upon the child. The loss of a near and dear relation, or a change of fortune, will often so much diminish the secretion of milk, as to render adventitious aid necessary for the support of the child. *Anxiety of mind* diminishes the quantity, and alters the quality, of the milk. The reception of a letter which leaves the mind in anxious suspense, lessens the draught, and the breast becomes empty. If the child be ill, and the mother is anxious respecting it, she complains to her medical attendant that she has little milk, and that her infant is griped, and has frequent green and frothy motions. *Fear* has a powerful influence on the secretion of milk. I am informed by a medical man who practises much among the poor, that the apprehension of the brutal conduct of a drunken husband, will put a stop for a time to the secretion of milk. When this happens, the breast feels knotted and hard, flaccid from the absence of milk, and that which is secreted is highly irritating, and some time elapses before a healthy secretion returns. *Terror*, which is sudden and great fear, instantly stops this secretion." Of this, two striking instances, in which the secretion, although previously abundant, was completely arrested by this emotion, are detailed by Sir A. C. "Those passions which are generally sources of pleasure, and which, when moderately indulged, are conducive to health, will, when carried to excess, alter, and even entirely check the secretion of milk."

950. There is even evidence that the Mammary secretion may acquire an actually *poisonous* character, under the influence of violent mental excitement; for certain phenomena which might otherwise be regarded in no other light than as simple coincidences, appear to justify this inference, when interpreted by the less striking but equally decisive facts already mentioned. "A Carpenter fell into a quarrel with a Soldier billeted in his house, and was set upon by the latter with his drawn sword. The wife of the Carpenter at first trembled from fear and terror, and then suddenly threw herself furiously between the combatants, wrested the sword from the soldier's hand, broke it in pieces, and threw it away. During the tumult, some neighbours came in and separated the men. While in this state of strong excitement, the mother took up her child from the cradle, where it lay playing, and in the most perfect health, never having had a moment's illness; she gave it the breast, and in so doing sealed its fate. In a few minutes the infant left off sucking,

became restless, panted, and sank dead upon its mother's bosom. The physician who was instantly called in, found the child lying in the cradle, as if asleep, and with its features undisturbed; but all his resources were fruitless. It was irrecoverably gone."* In this interesting case, the milk must have undergone a change, which gave it a powerful sedative action upon the susceptible nervous system of the infant.—The following, which occurred within the Author's own knowledge, is perhaps equally valuable to the Physiologist, as an example of the similarly-fatal influence of undue emotion of a different character; and both should serve as a salutary warning to mothers, not to indulge either in the exciting or depressing passions. A Lady having several children, of which none had manifested any particular tendency to cerebral disease, and of which the youngest was a healthy infant a few months old, heard of the death (from acute hydrocephalus) of the infant child of a friend residing at a distance, with whom she had been on terms of close intimacy, and whose family had increased almost contemporaneously with her own. The circumstance naturally made a strong impression on her mind; and she dwelt upon it the more, perhaps, as she happened, at that period, to be separated from the rest of her family, and to be much alone with her babe. One morning, shortly after having nursed it, she laid the infant in its cradle, asleep and apparently in perfect health; her attention was shortly attracted to it by a noise; and, on going to the cradle, she found her infant in a convulsion, which lasted a few moments and then left it dead. Now, although the influence of the mental emotion is less unequivocally displayed in this case than in the last, it can scarcely be a matter of doubt; since it is natural that no feeling should be stronger in the mother's mind under such circumstances, than the fear that her own beloved child should be taken from her, as that of her friend had been; and it is probable that she had been particularly dwelling on it, at the time of nursing the infant on that morning.—Another instance, in which the maternal influence was less certain, but in which it was not improbably the immediate cause of the fatal termination, occurred in a family nearly related to the Author's. The mother had lost several children in early infancy, from a convulsive disorder; one infant, however, survived the usually-fatal period; but whilst nursing him one morning, she had been strongly dwelling on the fear of losing him also, although he appeared a very healthy child. In a few minutes after the infant had been transferred into the arms of the nurse, and whilst she was urging her mistress to take a more cheerful view, directing her attention to his thriving appearance, he was seized with a convulsion-fit, and died almost

* Dr. Von Ammon, in his treatise "Die ersten Mutterpflichten und die erste Kindespflege," quoted in Dr. A. Combe's excellent little work on "The Management of Infancy."—Similar facts are recorded by other writers. Mr. Wardrop mentions ("Lancet," No. 516), that having removed a small tumour from behind the ear of a mother, all went well, until she fell into a violent passion; and the child, being suckled soon afterwards, died in convulsions. He was sent for hastily to see another child in convulsions, after taking the breast of a nurse who had just been severely reprimanded; and he was informed by Sir Richard Croft, that he had seen many similar instances. Three others are recorded by Burdach ("Physiologie," § 522); in one of them, the infant was seized with convulsions on the right side, and hemiplegia on the left, on sucking immediately after its mother had met with some distressing occurrence. Another case was that of a puppy, which was seized with epileptic convulsions, on sucking its mother after a fit of rage.

instantly. Now although there was here unquestionably a predisposing cause, of which there is no evidence in the other cases, it can scarcely be doubted that the *exciting* cause of the fatal disorder is to be referred to the mother's anxiety. This case offers a valuable suggestion,—which, indeed, would be afforded by other considerations,—that an infant, under such circumstances, should not be nursed by its mother, but by another woman of placid temperament, who has reared healthy children of her own.

951. Other Secretions are in like manner vitiated by mental Emotions, although the influence is not always so manifest. Thus, the halitus from the lungs is sometimes almost instantaneously affected by bad news, so as to produce fœtid breath. A copious secretion of fœtid gas not unfrequently takes place in the intestinal canal, under the influence of any disturbing emotion; or the usual fluid secretions from its walls are similarly disordered. The tendency to Defecation, which is commonly excited under such circumstances, is not, therefore, due simply to the relaxation of the sphincter ani (as commonly supposed); but is partly dependent on the unusually stimulating character of the fæces themselves. The same may be said of the tendency to Micturition, which is experienced under similar conditions; the change in the character of the urine becoming perceptible enough among many animals, in which it acquires a powerfully-disagreeable odour under the influence of fear, and thus answers the purpose which is effected in others by a peculiar secretion. It is a prevalent, and perhaps not an ill-founded opinion, that melancholy and jealousy have a tendency to increase the quantity, and to vitiate the quality, of the biliary fluid; perhaps the disorder of the organic function is more commonly the source of the former emotion, than its consequence; but it is certain that the indulgence of these feelings produces a decidedly morbific effect by disordering the digestive processes, and thus reacts upon the nervous system by impairing its healthy nutrition.

952. The influence of the Nervous System upon those formative processes which constitute the function of Nutrition, is less evident than it is upon the Secretory operations; and the nature of this influence is rather to be inferred from the results of its withdrawal, than to be demonstrated in any more direct manner. These results are chiefly to be seen in the altered nutrition of parts exposed to external impressions, as the integuments generally, but particularly those of the extremities; and they may be generally expressed by the statement, that the withdrawal of nervous influence from a part, renders it less able to withstand the destructive influence of physical agencies. It is certain, however, that a great part of the injurious effects which may be observed to follow injuries of the nerves of the extremities, experimentally inflicted, are traceable to want of power on the part of the animal, consequent upon the paralysed state of the limbs, to withdraw them from irritating impressions (§ 394 *note*), and must not be attributed to any direct deterioration of the formative operations, consequent upon the withdrawal of nervous agency. The following case, however, which is given by Mr. Paget* on the authority of Mr. Hilton, seems more unequivocally to establish this connexion. "A man was at Guy's Hospital, several years ago, who, in

* 'Lectures on Nutrition,' &c., in "Medical Gazette," 1847.

consequence of a fracture at the lower end of the radius repaired by an excessive quantity of new bone, suffered compression of the median nerve. He had ulceration of the thumb, and of the fore and middle fingers, which had resisted various treatment, and was cured only by so binding the wrist, that the parts on the palmar aspect being relaxed, the pressure on the nerve was removed. So long as this was done, the ulcers became and remained well; but as soon as the man was allowed to use his hand, the pressure on the nerves was removed, and the ulceration in the parts supplied by it returned." Mr. Paget also mentions the following curious case. "A lady who is subject to attacks of what are called nervous headaches, always finds next morning that some patches of her hair are white, as if powdered with starch. The change is effected in a night; and in a few days after, the hairs gradually regain their dark brownish colour."—That such effects are rather to be attributed to the loss or perversion of the influence of the Sympathetic System, than to that of the Cerebro-spinal, would appear from the fact noticed by Magendie and Longet, that destructive inflammation of the eye ensues more quickly after division of the Trigeminal nerve in front of the Gasserian ganglion, than when the division is made through the roots of the nerve, between that ganglion and the brain; the sympathetic filaments which exist largely in this nerve, being interrupted in their course to the tissues in the former case, but not in the latter. And this inference would be supported by the fact, that increased secretion of tears and mucus from the eye, and increased redness of the conjunctiva, are ordinary consequences of extirpation of the superior cervical ganglion of the sympathetic in dogs; and also with the general result of observation, that atrophy of parts supplied by the spinal nerves is much greater when the sensory as well as the motor roots are involved, than when the latter alone are paralysed,—it being through the ganglia and connecting filaments of the former, that the true Sympathetic fibres become incorporated with the Cerebro-spinal nerves.

953. The influence of the state of *expectant attention*, in modifying the processes of Nutrition and Secretion, is not less remarkable than we have already seen it to be in the production or modification of Muscular movements (§ 923). It seems certain that the simple direction of the consciousness to a part, independently of emotional excitement, but with the expectation that some change will take place in its organic activity, is often sufficient to induce such an alteration; and would probably always do so, if the concentration of the attention were sufficient. The most satisfactory exemplification of this principle has been given by the experiments of Mr. Braid, who has succeeded in producing very decided changes in the secretions of particular organs, by the fixation of the attention upon them in the 'hypnotic' state (§ 827). Thus he brought back an abundant flow of milk to the breast of a female who was leaving off nursing from defect of milk, and repeated the operation upon the other breast a few days subsequently, after which the supply was abundant for nine months; and in another instance he induced the catamenial flow on several successive occasions, when the usual time of its appearance had passed. It is not requisite, however, to produce the state of Somnambulism for this purpose, if the attention can be sufficiently drawn to the subject in any other mode; thus Mr. Braid has repeatedly produced the last-named

result on a female who possessed considerable power of mental concentration, by inducing her to fix her thoughts upon it for ten or fifteen minutes, so as to bring-on a state of reverie.—Now the effects which are producible by this *voluntary* direction of the consciousness to the result, are doubtless no less producible by that *involuntary* fixation of the attention upon it, which is consequent upon the eager expectation of benefit from some curative method in which implicit confidence is placed, or, on the other hand, upon that anticipation of unpleasant results in which some individuals are led to indulge by the morbid state of their feelings. It is to such a state that we may fairly attribute most, if not all, the cures, which have been worked by what is popularly termed the 'imagination.' The cures are real facts, however they may be explained; and there is scarcely a malady in which amendment has not been produced, not merely in the estimation of the patient, but in the more trustworthy opinion of medical observers, by practices which can have had no other effect than to direct the attention of the sufferer to the part, and to keep alive his confident expectation of the cure. The 'charming-away' of warts by spells of the most vulgar kind, the imposition of royal hands for the cure of the 'evil,' the pawings and strokings of Valentine Greatrakes, the manipulations practised with the 'metallic tractors,' the invocations of Prince Hohenlohe, *et hoc genus omne*,—not omitting the globulistic administrations of the Infinitesimal doctors, and the manipulations of the Mesmerists, of our own times,—have all worked to the same end, and have all been alike successful. It is unquestionable that, in all such cases, the benefit derived is in direct proportion to the *faith* of the sufferer in the means employed; and thus we see that a couple of bread pills will produce copious purgation, and a dose of *red* poppy syrup will serve as a powerful narcotic (as has happened within the personal knowledge of the Author), if the patient have been led to feel a sufficiently confident expectation of the respective results of these medicaments.*—This state of confident expectation, however, may operate for evil, no less than for good. A fixed belief that a mortal disease had seized upon the frame, or that a particular operation or system of treatment would prove unsuccessful, has been in numerous instances (there is no reason to doubt) the direct cause of a fatal result. And thus the morbid feelings of the hypochondriac, who is constantly directing his attention to his own fancied ailments, tend to induce real disorder in the action of the organs which are supposed to be affected. In the same category, too, may be placed those instances (to which alone any value is to be attached), wherein *a strong and persistent impression* upon the mind of a mother, has appeared to produce a corresponding effect upon the development of the *fœtus in utero.* In this case, the effect (if admitted to be really exerted) must be produced upon the maternal blood, and transmitted through it

* It is commonly said that these effects are produced by the *imagination;* but this only serves to induce the belief that the *sham* remedy is one of *real* efficacy; and it is the state of 'expectant attention' which is the *immediate* operating agent, and which is necessary to the result.—In whatever mode this can be induced, the effect will be the same. Thus Dr. Haygarth of Bath (in conjunction with Mr. Richard Smith of Bristol) tested the value of the 'metallic tractors,' by substituting two pieces of wood painted in imitation of them, or even a pair of tenpenny nails disguised with sealing-wax, or a couple of slate-pencils; which they found to possess all the virtues that were claimed for the real instruments, because the state of 'expectant attention' was equally induced by either.

ɔ the fœtus; since there is no nervous communication between the arent and offspring. There is no difficulty, however, in understanding ow this may occur, after what has been stated on a former occasion § 203) of the influence of minute alterations in the condition of the lood, in determining local alterations of nutrition.

## CHAPTER XIX.

### OF GENERATION.

#### 1.—*General Character of the Function.*

954. Having now passed in review the various operations which are oncerned in maintaining the life of the *individual*, we have next to proeed to those which are destined to the perpetuation of the *race*, by the roduction of successive generations of similar beings. In Man and the igher animals, this function is performed in only one method; namely, y the development of an *ovum* in the Female, which, when fertilized by he *spermatozoon* of the Male, gives origin within itself to a new being; he embryo, if supplied with the requisite nourishment, warmth, &c., radually evolving itself into the likeness of its parents. This process ppears, as will presently be shown, to be performed in a manner essenially the same, not only throughout the Animal kingdom, but through he Vegetable kingdom also. But among Plants, and the lower tribes of nimals, we find an additional method of propagation; for, without any exual process whatever, new beings may be formed by *gemmation* or budding' from the parent-stock, and these, gradually becoming less and ess dependent upon it, at last detach themselves and maintain a separate xistence. Now this process may be regarded as essentially the same with hat of the multiplication of cells by *subdivision*, which we have seen to e the most common mode of propagation in the simplest cellular Plants § 104); and it differs from the ordinary operations of growth and deveopment in no other particular than this,—that the newly-formed strucure, instead of remaining as a constituent and dependent part of the arental fabric, is capable of living independently of it, and of thus existig as a distinct individual when spontaneously or artificially detached. mong the higher tribes of Animals, as in Man, this mode of multiplicaion of individuals does not present itself, at least in the adult state; for n no instance do we find that a part of the body separated from the rest an develope the organs which are necessary for the sustenance of its xistence; and the power which the organism possesses, of regenerating arts which it has lost by disease or accident, is restrained within very arrow limits (§ 599). But there is good ground to believe, that such a ultiplication by subdivision *may* take place at that earliest period of mbryonic life, at which the germ is nothing else than a mass of cells, herein no distinction of parts has as yet manifested itself; and that the roduction of two complete individuals, only held together by a conecting band, may arise from some cause which determines the subdivision f the germinal mass, at the period when its grade of development cor-

responds with that of the Hydra or Planaria.* And this view of the case is confirmed by the facts already stated (§ 599), in regard to the higher degree of the regenerating power during embryonic life, infancy, and childhood, as compared with that which remains after the development of the fabric has been completed.

955. We have now to consider, however, the proper act of Generation, which uniformly involves the union of the contents of two peculiar cells, which may be designated 'sperm-cells,' and 'germ-cells.'† Recent discoveries render it almost certain that this true generative process occurs throughout the Vegetable kingdom, and is not confined, as was formerly supposed, to Flowering Plants.‡ It appears to take place in three modes; which are all, however, but variations of one fundamental plan.—1. In the simplest Cellular Plants, in which every cell appears to possess the same endowments, so that there is no kind of specialization of function, the generative act consists in the 'conjugation' of two of the ordinary cells, between which no difference can be traced. In what may be considered the lowest types of this process, *both* cells discharge their contents, and the new body or *sporangium* is formed between them by the mixture of their 'endochromes;' each cell appearing to have precisely the same share in the process, so that no distinction of 'sperm-cells' and 'germ-cells' can be said here to exist. This, however, is precisely what might be expected, when it is remembered that no distinction presents itself between any other organs, such as the root and leaf; each cell having endowments to all appearance identical with those of the rest of the mass. But the generative process, in this which may be regarded as its simplest and most essential form, shows itself to be the precise counterpart of the process of 'fission' already described (§ 104); for as in the latter one cell divides itself into equal halves, between which no difference can be traced, so, in the act of 'conjugation,' the contents of two cells, apparently similar, reunite, and form but a single new cell between them. In virtue of that union, a new force seems to be developed, which leads to the multiplication of this first cell by repeated subdivision, until the germ-force is expended, when a fresh conjugation occurs. This reunion of the cell-contents may take place, either by the rupture of both cells and the discharge of their endochromes, around which, after their admixture, a new cell-wall is formed (Fig. 150, A, 1), or by the formation of a direct communication from the interior of one to that of the other; in which latter case the union of the two endochromes may take place either in the connecting channel (A, 2), or in one of the cells of the pair (A, 3), within which the sporangium is formed and matured. It is in certain of the Desmideæ and Zygnemata, that we meet with this latter type; which presents us with the first distinction between the 'sperm-cell' and the 'germ-cell.'—2. In the higher Algæ, and in all the superior Cryptogamia, the process is effected by the agency of moving filaments, precisely

* See Prof. Allen Thomson on 'Double Monstrosity,' in the "Edinb. Monthly Journ.," June and July, 1844; and Prof. Vrolik's Article 'Teratology' in the "Cyclop. of Anat. and Phys.," vol. iv.

† These terms are adopted from Prof. Owen. See his "Lectures on Parthenogenesis," London, 1849.

‡ "For a general account of these discoveries, see the "British and Foreign Medico-Chirurgical Review," Oct. 1849; and "Princ. of Phys., Gen. and Comp.," CHAP. XVIII.

resembling the spermatozoa of Animals, and developed within special 'sperm-cells' in a mode precisely the same with the evolution of the spermatozoa of Animals (§ 959); these appear to find their way to the germ-cells, which are sometimes developed within the same receptacles, sometimes in distinct receptacles on the same plant, and sometimes in different plants; and as the result of their contact with the germ-cells,

FIG. 150.

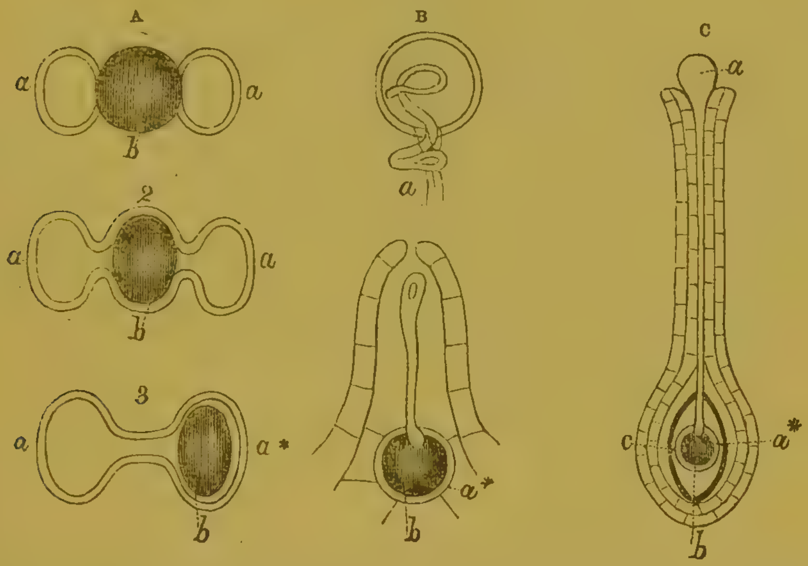



Diagram representing the three principal forms of the *Generative Process in Plants:*—A, conjugation of inferior Cryptogamia; formation of the sporangium, *b*, by admixture of the discharged endochromes of the parent-cells, *a*, *a;* 2, production of the sporangium, *b*, within a dilatation formed by the union of the two parent-cells; 3, production of the sporangium, *b*, by the passage of the endochrome of cell *a* into that of cell *a**, marking-out a sexual difference.—B, fertilization of germ in higher Cryptogamia; *a*, sperm-cell discharging its spiral filament, *a**, germ-cell, against which one of these filaments is impinging, *b*, germ produced by their contact.—C, fertilization of germ in Phanerogamia; *a*, sperm-cell, or pollen-grain, sending its prolonged tube down the style, until it reaches *a** the germ-cell, inclosed in the ovule, the section of whose coats is shown at *c;* from the contact of the two, is produced the germ *b*.

the embryo originates in the interior of the latter (Fig. 150, B). This embryo, in the lower Cryptogamia, is at once cast upon its own resources; whilst in the higher it is nourished, during its early development, by food supplied to it by the parent. In no case, however, does the parent appear to furnish that accumulation of nutritive matter for the development of the product of the germ-cell, which, when included in a common envelope with it, would constitute a true 'seed.'—3. In the Flowering Plants, the 'sperm-cell' (or pollen-grain) does not evolve a self-moving filament, as in the Cryptogamia; but puts forth a long tube, which, insinuating itself between the soft loose tissue of the 'style,' conveys the fertilizing influence to the 'germ-cell' (or embryonic vesicle of the ovule) after a different fashion (Fig. 150, C); still, however, fulfilling the same essential purpose as that which the simple 'conjugation' of the lowest Algæ effected, namely, the mingling of the contents of the 'sperm-cell' and 'germ-cell,' which takes place by transudation through the thin membranes of the pollen-tube and of the embryonic vesicle. The germ-cell is here surrounded by a mass of nutritious matter, which, with the embryo, constitutes the 'seed;' and it is upon this store, that the young plant subsists during the early stages of its development.

956. The 'act of Generation' in Animals may be said to combine the

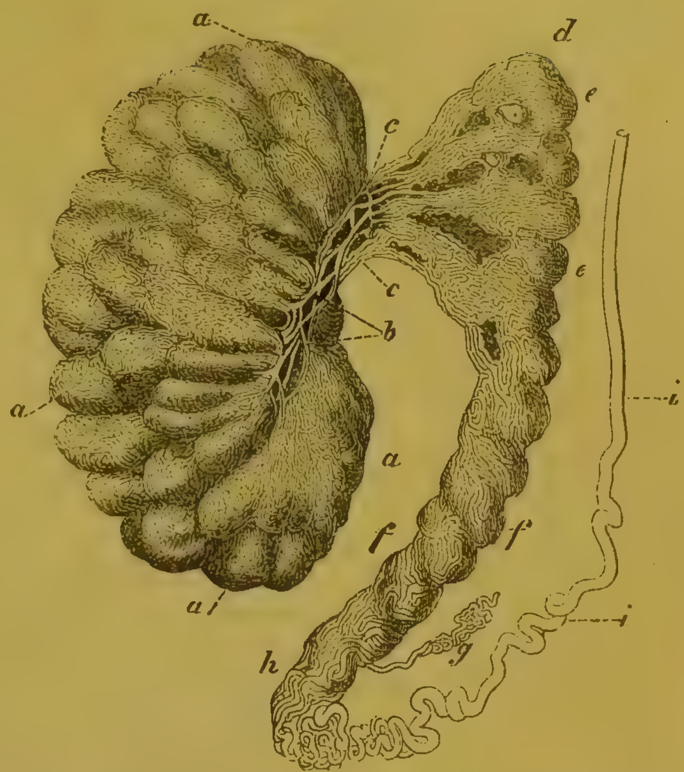
principal features of the second and third of the above methods; for, as in the higher Cryptogamia, the 'sperm-cells' of Animals seem invariably to form the self-moving filaments known as Spermatozoa; whilst the 'germ-cells,' instead of being naked (as in the Cryptogamia), are surrounded (as in Flowering Plants) by a mass of nutriment destined to serve for the early development of the embryo; this mass with its contained germ-cell being known as the *ovule* before it has been fertilized, and as the *ovum* or egg after fecundation has taken place. There is a great difference, however, among the different tribes of Animals, as to the degree of assistance thus afforded to the embryo; the general rule being, that the higher the form which the embryo is ultimately to attain, the longer is it supported by its parent. Hence we find the embryos of most Invertebrated animals coming forth from the egg in a condition very much unlike their perfect type, and only acquiring this after a long succession of subsequent alterations, which frequently involve a complete change of form, or *metamorphosis.* In Fishes, however, the embryo, though far from having completed its embryonic development at the time of its emersion from the egg, does not differ so widely from the adult type. In Birds, there is a provision for a much more advanced development; the store of nutritious matter, or 'yolk,' being so large as to allow the whole series of changes requisite for the formation of the complete chick, to take place before it leaves the egg. In the Mammalia, on the contrary, the quantity of yolk contained in the ovum is very small, but the embryo is only dependent upon it for the materials of its increase during the earliest stages of its evolution; for it speedily forms a special connection with the parent-structure, by means of which it is enabled to receive a continual supply of newly-prepared aliment, so as to be supported at the expense of this until far advanced in its development. Some approaches to this arrangement are met-with among certain of the lower Animals, but it is only in the higher Mammalia, that it is completely carried out; and it is only in this class, too, that we find a supplemental provision for the nutrition of the offspring after it has come forth into the world. In many of the lower tribes of Animals, the fertilization of the ova is accomplished without any sexual congress; the spermatic fluid effused by the male, coming into direct contact with the ova previously deposited by the female; but in all the higher tribes, as in Man, the spermatic fluid is conveyed into the oviducts of the female, that it may impregnate the ovum shortly after it has quitted the ovarium, or even before its final escape from it.—With these general views, we shall now be prepared to examine into the history of the act of Generation in Man, and to consider the share which each sex has in its performance.

### 2.—*Action of the Male.*

957. The Spermatic fluid of the Male is secreted by glandular organs, known as *Testes.* Each of these consists of several lobules, which are separated from each other by processes of the Tunica Albuginea that pass down between them, and also by an extremely delicate membrane (described by Sir A. Cooper under the name of Tunica Vasculosa) consisting of minute ramifications of the spermatic vessels united by areolar tissue. Each lobule is composed of a mass of convoluted *tubuli seminiferi,* through-

out which blood-vessels are minutely distributed. The lobules differ greatly in size, some containing one, and others many of the tubuli; the total number of the lobules is estimated at about 450 in each testis, and that of the tubuli at 840. The convolutions of the tubuli are so arranged, that each lobule forms a sort of cone, the apex of which is directed towards the Rete Testis. It is difficult to trace the free extremities of the Seminiferous tubes, owing to the frequency of their anastomoses with each other; in this respect, therefore, the structure of the testis accords closely with that of the Kidney. The diameter of the tubuli is for the most part very uniform; in the natural condition they seem to vary from about the 1-195th to the 1-170th of an inch; but when injected with mercury, they are distended to a size nearly double the smaller of these dimensions. When they have reached to within a line or two of the rete testis, they cease to be convoluted, several unite together into tubes of larger diameter, and these enter the rete testis under the name of *tubuli recti.* The *rete testis* consists of from seven to thirteen vessels, which run in a waving course, anastomose with each other, and again divide, being all connected together. The *vasa effe-*

FIG. 151.




*Human Testis*, injected with mercury as completely as possible:—*a, a*, lobules formed of the seminiferous tubes; *b*, rete testis; *c*, vasa efferentia; *d*, flexures of the efferent vessels passing into the head *e, e*, of the epididymis; *f*, body of the epididymis; *g*, appendix; *h*, cauda; *i*, vas deferens.

FIG. 152.


Plan of the structure of the *Testis* and *Epididymis*:—*a, a*, seminiferous tubes; *a*, a**, their anastomoses; the other references as in the last figure.

*rentia* which pass to the head of the epididymis are at first straight, but soon become convoluted, each forming a sort of cone, of which the apex is directed towards the rete testis, the base to the head of the epididymis. The number of these is stated to vary from nine to thirty; and their length to be about eight inches. The *epididymis* itself consists of a very convoluted canal, the length of which is about twenty-one feet. Into its lower extremity, that is, the angle which it makes where it terminates in the vas deferens, is poured the secretion of the *vasculum aberrans* or appendix; which seems like a testis in miniature, closely resembling a single lobule in its structure. Its special function is unknown.—The fluid secreted by the Testis is thick, tenacious, and of a greyish or yellowish colour. It is mingled, during or before emission, with fluid secreted by the Prostate, Cowper's gland, &c.; and it cannot, therefore, be obtained pure, but by drawing it from the testicle itself; hence no accurate analysis can be made of it in the Human subject. The peculiar odour which the Semen possesses, does not appear to belong to the proper spermatic fluid; but is probably derived from one or other of the secretions with which it is mingled. The chemical analyses which have been made of this fluid are all defective, inasmuch as they do not distinguish the real secretion of the testes from the mucus, prostatic fluid, &c. with which it is mingled. It may be stated, however, that it has an alkaline reaction, and contains albumen, with a peculiar animal principle termed Spermatin; and also saline matter, consisting chiefly of muriates and phosphates, especially the latter, which form crystals when the fluid has stood for some little time.

958. The essential peculiarity of the Spermatic fluid consists in the presence of a large number of very minute bodies, only discernible with a high power of the Microscope; and these, in ordinary cases, remain in active motion for some time after they have quitted the living organism. The Human Spermatozoon (of which representations are given in Plate I., Fig. 1) consists of a little oval flattened 'body' between the 1-600th and the 1-800th of a line in length, from which proceeds a long filiform 'tail' gradually tapering to the finest point, of 1-50th or at most 1-40th of a line in length. The whole is perfectly transparent; and nothing that can be termed structure can be satisfactorily distinguished within it. Its movements are principally executed by the tail, which has a kind of vibratile undulating motion. They may continue for many hours after the emission of the fluid; and they are not checked by its admixture with other secretions, such as the urine and the prostatic fluid. Thus, in cases of nocturnal emission, the Spermatozoa may not unfrequently be found actively moving through the urine in the morning; and those contained in the seminal fluid collected from females that have just copulated, are frequently found to live many days. Their presence may be readily detected by a Microscope of sufficient power, even when they have long ceased to move, and are broken into fragments; and the Physician and the Medical Jurist will frequently derive much assistance from an examination of this kind. Thus, cases are of no uncommon occurrence, especially among those who have been too much addicted to sexual indulgence, in which seminal emissions take place unconsciously and frequently, and produce great general derangement of the health; and the true nature of the complaint is obscure, until the fact has been detected by ocular

examination. Again, in charges of rape, in which evidence of actual emission is required, a microscopic examination of the stiffened spots left on the linen will seldom fail in obtaining proof, if the act have been completed: in such cases, however, we must not expect to meet with more than fragments of Spermatozoa; but these are so unlike anything else, that little doubt need be entertained regarding them. It has been proposed to employ the same test, in juridical inquiries respecting doubtful cases of death by suspension, seminal emissions being not unfrequent results of this kind of violence; but there are many obvious objections which should prevent much confidence being placed in it.*

959. The mode of evolution of the Spermatozoa, first discovered by Wagner, and more perfectly elucidated by Kölliker, is such as to indicate that these bodies are true products of the formative action of the organs in which they are found, and cannot be ranked (as they long were) in the same category with Animalcules. They are developed in the interior of cells, or 'vesicles of evolution,' such as are visible in the seminal fluid in various stages of development (Plate I, Fig. 2, A, B, C), and have been known under the name of 'seminal granules.' These appear to have been themselves formed within parent-cells, which are probably to be regarded as the epithelial cells of the tubuli seminiferi; constituting, like the analogous cells of other glands, the essential elements of the spermatic apparatus.† These parent-cells are sometimes observed to contain but a single 'vesicle of evolution,' as shown at D; but more commonly three, four, six, or seven are to be seen within them (E). When taken from a body recently dead, and examined without being treated with water or any other agent, they are quite pellucid, and exhibit a delicate contour with perfectly homogeneous contents; very speedily, however, a sort of coagulation takes place within them, by which their contents are rendered granular. Each of these 'vesicles of evolution' gives origin to a spermatozoon, and to one only; the earliest stages of its development have not yet been distinctly made out, since it does not at first exhibit those sharp distinct contours, dependent on its great refractive power, which afterwards distinguish it; but it is seen lying in the interior of the cell as a slight linear shadow, at first partly hidden by the surrounding granules (Fig. 3, B), but afterwards without any such obscuration. When the vesicle is completely matured, it bursts, and gives exit to the contained spermatozoon, which, thenceforth, in the Mammalia, usually moves freely in the spermatic fluid; in Birds, however, it is more common for the parent-cells to retain the vesicles of evolution during the development of the Spermatozoa within the latter; so that when these set free the Spermatozoa, they are still enveloped by the parent-cell. In this condition they have a tendency to aggregation in bundles; and these bundles are finally liberated by the rupture of the parent-cell, after which the individual spermatozoa separate from one another. Such bundles may be occasionally seen in the Human semen.—That the Spermatozoa are the essential elements of the spermatic fluid, may be reasonably inferred from several considerations. There are some cases in which the

* See the Author's Article 'Asphyxia,' in the "Library of Practical Medicine," and the authorities there referred to.

† In the Hydra and other Zoophytes, such cells are found imbedded in the general substance of the body, instead of being developed within a special organ.

'liquor seminis' is altogether absent, so that they constitute the sole element of the semen; whilst, on the other hand, they are never wanting in the semen of animals capable of procreation; but are absent, or imperfectly developed, in the semen of hybrids, which are nearly or entirely sterile. Moreover, we have every reason to believe that, in the higher animals, the absolute contact of the spermatozoa with the ovum is requisite for its fecundation; whilst, on the other hand, if the spermatozoa be carefully removed from the liquor seminis by filtration, the latter is found to be entirely destitute of fertilizing power.*—It is interesting to remark, that the perfectly-developed spermatozoa possess the same chemical composition with the epithelial tissues in general.†

960. The power of procreation does not usually exist in the Human Male, until the age of from 14 to 16 years; and it may be considered probable that no Spermatozoa are produced until that period, although a fluid is secreted by the testes. At this epoch, which is ordinarily designated as that of Puberty, a considerable change takes place in the bodily constitution: the sexual organs undergo a much-increased development; various parts of the surface, especially the chin and the pubes, become covered with hair; the larynx enlarges, and the voice becomes lower in pitch, as well as rougher and more powerful; and new feelings and desires are awakened in the mind. Instances, however, are by no means rare, in which these changes take place at a much earlier period; the full development of the generative organs, with manifestations of the sexual passion, having been observed in children of but a few years old. The procreative power may last, if not abused, during a very prolonged period. Undoubted instances of virility at the age of more than 100 years are on record; but in these cases, the general bodily vigour was preserved in a very remarkable degree. The ordinary rule seems to be, that sexual power is not retained by the male to any considerable amount, after the age of 60 or 65 years.—To the use of the sexual organs for the continuance of his race, Man is prompted by a powerful instinctive desire (§ 772), which he shares with the lower animals. This Instinct, like the other propensities, is excited by sensations; and these may either originate in the sexual organs themselves, or may be excited through the organs of special sensation. Thus in Man it is most powerfully aroused by impressions conveyed through the sight or the touch; but in many other animals, the auditory and olfactive organs communicate impressions which have an equal power; and it is not improbable that, in certain morbidly-excited states of feeling, the same may be the case in ourselves. That local impressions have also a very powerful effect in exciting sexual desire, must have been within the experience of almost every one; the fact is most remarkable, however, in cases of Satyriasis, which disease is generally found to be connected with some obvious cause of irritation of the generative system, such as pruritus, active congestion, &c. That some part of the Encephalon is the seat of this as of other instinctive propensities, appears from the considerations formerly adduced; but that

* This point has been completely established by the researches of Mr. Newport ("Phil. Trans.," 1851), who has repeated and confirmed the experimental results previously obtained by Spallanzani and by Prevost and Dumas.

† For the latest researches on the development, &c., of the Spermatozoa, see the elaborate Article 'Semen,' in the "Cyclop. of Anat. and Physiol.," by Drs. Wagner and Leuckardt.

the Cerebellum is the part in which this function is specially located, cannot be regarded as by any means sufficiently proved (§§ 767—772). The instinct, when once aroused (even though very obscurely felt), acts upon the mental faculties and moral feelings; and thus becomes the source, though almost unconsciously so to the individual, of the tendency to form that kind of attachment towards one of the opposite sex, which is known as *love*. This tendency cannot be regarded as a simple passion or emotion, since it is the result of the combined operations of the reason, the imagination, and the moral feelings; and it is in this engraftment (so to speak) of the psychical attachment, upon the mere corporeal instinct, that a difference exists between the sexual relations of Man and those of the lower animals. In proportion as the Human being makes the temporary gratification of the mere sexual appetite his chief object, and overlooks the happiness arising from spiritual communion, which is not only purer but more permanent, and of which a renewal may be anticipated in another world,—does he degrade himself to the level of the brutes that perish. Yet how lamentably frequent is this degradation!

961. When, impelled by sexual excitement, the Male seeks intercourse with the Female, the erectile tissue of the genital organs becomes turgid with blood (§ 534), and the surface acquires a much-increased sensibility; this is especially acute in the Glans penis. By the friction of the Glans against the rugous walls of the Vagina, the excitement is increased; and the impression which is thus produced at last becomes so strong, that it calls-forth, through the medium of the Spinal Cord, a reflex contraction of the muscles which surround the Vesiculæ Seminales. These receptacles discharge their contents (partly consisting of semen and partly of a secretion of their own) into the Urethra; and from this they are expelled with some degree of force, and with a kind of convulsive action, by its own Compressor muscles. Now although the sensations concerned in this act are ordinarily most acutely pleasurable, there appears sufficient evidence that they are by no means essential to its performance; and that the impression which is conveyed to the Spinal Cord *need not* give rise to a sensation, in order to produce the reflex contraction of the Ejaculator muscles (§ 723). The high degree of nervous excitement which the act of coition involves, produces a subsequent depression of corresponding amount; and the too frequent repetition of it is productive of consequences very injurious to the general health. This is still more the case with the solitary indulgence, which (it is to be feared) is practised by too many youths; for this, substituting an unnatural degree of one kind of excitement, for that which is wanting in another, cannot but be still more trying to the bodily powers. The secretion of seminal fluid being, like other secretions, very much under the control of the nervous system, will be increased by the continual direction of the mind towards objects which awaken the sexual propensity (§ 948, *note*); and thus, if intercourse be very frequent, a much larger quantity will altogether be produced, although the amount emitted at each period will be less. The formation of the secretion seems of itself to be a much greater tax upon the corporeal powers, than might have been supposed *à priori*: and it is a well-known fact, that the highest degree of bodily vigour is inconsistent with more than a very moderate indulgence in sexual intercourse; whilst nothing is more certain to reduce the powers, both of body and mind,

than excess in this respect. These principles, which are of great importance in the regulation of the health, are but results of the general law, which prevails equally in the Vegetable and Animal kingdoms,—that the Development of the Individual, and the Reproduction of the Species, stand in an inverse ratio to each other.

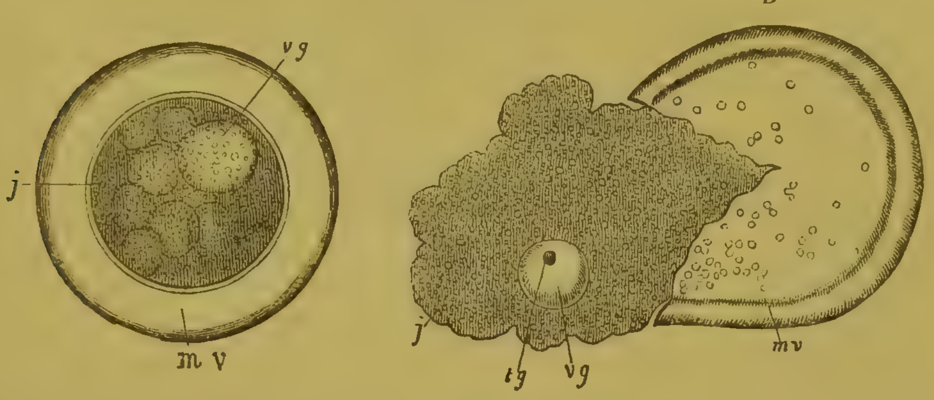
### 3. *Action of the Female.*

962. The essential part of the Female Generative system, is that in which the Ova are prepared; the other organs are merely accessory, and are not to be found in a large proportion of the Animal kingdom. In many of the lower animals, the Ovaria and Testes are so extremely like each other, that the difference between them can scarcely be distinguished; and the same is true regarding the condition of these organs in Man, at an early period of development. The fact is one of no small interest. In many of the lower animals, the Ovarium consists of a loose tissue containing many cells, in which the Ova are formed, and from which they escape by the rupture of the cell-walls; in the higher animals as in the Human female, the tissue of the Ovarium is more compact, forming what is known as the *stroma;* and the Ova, except when they are approaching maturity, can only be distinguished in the interstices of this, by the aid of a high magnifying power. The Ovum in all Vertebrated animals is produced within a capsule or bag, the exterior of which is in contact with the stroma of the ovarium; this has been termed, in Mammalia, the *Graafian vesicle*, after the name of its first discoverer; but the more general and appropriate designation of *Ovisac* has been given to it by Dr. Barry, who has shown that it exists in other classes of Vertebrata. Between the Ovum and the Ovisac, in Oviparous animals, there is scarcely any interval; but in the Mammalia, a large amount of granular matter (composed of nucleated cells, loosely aggregated together) is present; being especially found adherent to the lining of the ovisac, to which it forms a sort of epithelium, or internal tunic, known as the *membrana granulosa;* whilst it also forms a disk-like investment to the ovum, which is termed the *discus proligerus.* The membrane which incloses the yolk in Mammalia, has received, on account of its thickness and peculiar transparency, the distinctive appellation of *zona pellucida* (Fig. 153, *m v*).—The yolk, or *vitellus* (*j*), which is composed of albumen and oil-particles, with traces of cells, is very small in the Mammalian ovum, its function being limited to the sustenance of the germ during its earliest period of development; and it corresponds rather with that part of the yolk of the egg of the higher Ovipara which has been distinguished as the 'germ-yolk,' in consequence of its direct participation in the formation of the germinal substance (§ 995), than with that which has been termed the 'food-yolk,' as not being incorporated with the germ, but being destined for its subsequent nutrition by undergoing conversion into blood.* Occupying the centre of the vitelline mass, in the immature

* It has been recently maintained by Reinhardt, that the Bird's yolk-bag is really homologous with the Graafian vesicle of the Mammal and its entire contents; the 'food-yolk' of the former being represented in the latter by the cellular substance surrounding the zona pellucida, which is afterwards developed into the corpus luteum. (Kölliker and Siebold's Zeitschrift, band iii. heft 4.)

ovulum, is a peculiar cell, very different in its aspect from the surrounding substance, which is termed the *germinal vesicle* (Fig. 153, *v g*); and this has a very distinct nucleus (*t g*) known as the *germinal spot*. This cell must be considered as the essential part of the ovum, and as homologous with the 'germ-cell' or 'embryonic vesicle' of the Vegetable ovule. —The Human Ovum is extremely minute; not measuring above 1-120th

Fig. 153.




Constituent parts of *Mammalian Ovum*:—A, entire; B, ruptured, with the contents escaping; —*m v*, vitelline membrane; *j*, yolk; *v g*, germinal vesicle; *t g*, germinal spot.

of an inch in diameter, and being sometimes of no more than half that size. The diameter of the germinal vesicle of the human ovum has not yet been ascertained, owing to the difficulty of isolating it from the yolk; in the ovum of the rabbit, it is about 1-720th of an inch; and that of the germinal spot, in the Mammalia generally, is from 1-3600th to 1-2400th of an inch.

963. It appears, from the researches of Valentin and Bischoff, that the Graafian vesicle, or Ovisac, is formed previously to the Ovum, which is subsequently developed in its interior; and it would seem that we may regard it as a *vesicle of evolution* for the ovum, in the same way that the gland-cells of the testis act as vesicles of evolution for the spermatozoa. The development of ovisacs commences at a very early period of life; in the ovaries of some animals, they can be detected almost as soon as these organs are themselves evolved; and in all, they show themselves soon after birth. In Plate I., Fig. 4, is represented the condition of the Graafian vesicles in various stages of development, as they are seen imbedded in the fibrous stroma of the ovarium, in a thin slice from the ovary of a sow three weeks old; by which time the germinal vesicle, which is the first part of the ovum that makes its appearance, has been developed in their interior. The germinal vesicle, which distinctly shows the germinal spot, is surrounded by an assemblage of granules, which is the first indication of a yolk; and around these the zona pellucida appears to be subsequently developed. The ovum at first occupies the centre of the Graafian vesicle, but it subsequently removes to its periphery; and, when the contents of the ovisac are undergoing maturation, prior to their escape, the ovum is always found on the side of it nearest to the surface of the ovary. The proper ovisac, whose wall is formed of a non-vascular membrane, is surrounded by a vascular layer, which is formed by a condensation of the ordinary stroma of the ovarium; it is this which is reckoned as the outer layer of the Graafian vesicle.

964. A continual change seems to be taking place in the contents of the ovarium, during the greater part of life; certain of the ovisacs or Graafian vesicles, and their contents, successively arriving at maturity, whilst others degenerate and die. According to the valuable inquiries of Dr. Ritchie,* it appears that, even during the period of childhood, there is a continual rupture of ovisacs and discharge of ova, at the surface of the ovarium. The Ovaria are studded with numerous minute copper-coloured maculæ, and their surface presents delicate vesicular elevations, which are occasioned by the most matured ovisacs; the dehiscence of these takes place by minute punctiform openings in the peritoneal coat, and no cicatrix is left. At the period of puberty, the stroma of the ovarium is crowded with ovisacs; which are still so minute, that in the Ox (according to Dr. Barry's computation) a cubic inch would contain 200 *millions* of them. The greatest advance is seen in those which are situated nearest the surface of the Ovarium; and in such the Graafian vesicle, with its two coats, may be distinctly traced. In those animals whose aptitude for conception is periodical, the development of the ova, to such a degree that they become prepared for fecundation, is periodical also. This development is made evident, when the parts are examined in an animal which is "in heat," by the projection of the Graafian vesicles from the surface (Fig. 154); and it consists not merely in an increase of size, but in certain internal changes presently to be described.

Fig. 154.

*Ovarium of the Rabbit*, at the period of Heat; showing various stages of the extrusion of ova.

965. In the Human female, the period of Puberty, or of commencing aptitude for procreation, is usually between the 13th and 16th years; it is generally thought to be somewhat earlier in warm climates than in cold,† and in densely-populated manufacturing towns than in thinly-peopled agricultural districts. The mental and bodily habits of the individual have also considerable influence upon the time of its occurrence; girls brought up in the midst of luxury or sensual indulgence, undergoing this change earlier than those reared in hardihood and self-denial. The changes in which puberty consists, are for the most part connected with the Repro-

* "London Medical Gazette," 1844.

† It has been stated, by almost all physiological writers, that women (like fruits) reach maturity and that menstruation commences, much earlier in hot climates, particularly between the tropics, than in temperate and very cold countries; from many elaborate and interesting papers which have been published within a few years, however, especially from those of Mr. Roberton of Manchester (recently collected in his "Essays on Menstruation, and on Practical Midwifery," 1851), it would seem that the natural period of puberty in temperate climates occurs in a much more extended range of ages, and is much more equally distributed through that range, than others have alleged; and that, in other countries, the supposed parallel between plants and fruits does not hold good. The fact seems to be, that this, like other *periodic* phenomena of warm-blooded animals, is but little influenced by external temperature, simply because the rate of growth and development, of which these phenomena are the exponents, is determined by the temperature of the body itself, not by that of the surrounding medium. Still it is quite possible that external warmth may have a slight influence in determining early puberty; since, as already shown, it tends to maintain a somewhat higher degree of bodily heat (§ 651).

ductive system. The external and internal organs of generation undergo a considerable increase of size; the mammary glands enlarge; and a deposition of fat takes place in the mammæ and on the pubes, as well as over the whole surface of the body, giving to the person that roundness and fulness, which are so attractive to the opposite sex at the period of commencing womanhood. The first appearance of the Catamenia usually occurs whilst these changes are in progress, and is a decided indication of the arrival of the period of puberty; but it is not unfrequently delayed much longer; and its absence is by no means to be regarded as a proof of the want of aptitude for procreation, since many women have borne large families, without having ever menstruated. The Catamenial discharge, as it issues from the uterus, appears to be nearly or quite identical with ordinary blood; but in its passage through the vagina, it becomes mixed with the acid mucus exuded from its walls, which usually deprives it of the power of coagulating. If the discharge should be profuse, however, a portion of its fibrin remains unaffected, and clots are formed. In cases in which, by the death of women at this period, an opportunity has been afforded for the examination of the lining membrane of the uterus during menstruation, it is found to be unusually turgid with blood, the veins in particular being much distended, and opening upon the internal surface by capillary orifices, to which valvules are occasionally found attached.* Hence it is scarcely correct to designate the menstrual flux as a 'secretion;' although there is reason to think that it may carry off, besides blood, certain matters which would be appropriate to the formation of a decidual membrane, but which, if not so employed, become excrementitious.—The interval which usually elapses between the successive appearances of the discharge, is about four weeks; and the duration of the flow is from three to six days. There is great variety, however, in this respect among the inhabitants in different climates, and among individuals; in general, the appearance is more frequent, and the duration of the flow greater, among the residents in warm countries, and among individuals of luxurious habits and relaxed frame, than among the inhabitants of colder climes, or among individuals inured to bodily exertion. The first appearance of the discharge is usually preceded and accompanied by considerable general disturbance of the system; especially pain in the loins and a sense of fatigue in the lower extremities; and its periodical return is usually attended with the same symptoms, which are more or less severe in different individuals.

966. Much discussion has taken place respecting the causes and purposes of the Menstrual flow; and recent inquiries have thrown much light upon them. The state of the female generative system, during its continuance, appears to be analogous to the *heat* of the lower animals, many of which have a sero-sanguinolent discharge at that period. There is good reason to believe that in the Human female the sexual feeling becomes stronger at that epoch; and it is quite certain that there is a greater aptitude for Conception, immediately before and after menstruation, than there is at any intermediate period. Observations to this effect were made by Hippocrates, and were confirmed by Boerhaave and Haller; indeed coitus immediately after menstruation appears to have been frequently recommended as a cure for sterility, and to have proved success-

* See Whitehead "On Abortion and Sterility," pp. 13, 27.

ful. It is well known that, among many of the lower animals, the ova are entirely extruded by the female, before the spermatic fluid of the male reaches them; and that even in Birds, this occasionally takes place. This question has been made the subject of special inquiry by M. Raciborski; who affirms that the exceptions to the rule—that conception occurs immediately before or after, or during menstruation—are not more than 6 or 7 per cent. Indeed, in his latest work on this subject,* he gives the details of 15 cases, in which the date of conception could be accurately fixed, and the time of the last appearance of the catamenia was also known; and in all but one of them, the correspondence between the two periods was very close. Even in the exceptional case, the catamenia made their appearance shortly after the coitus; which took place at about the middle of the interval between the two regular periods. When conception occurs immediately before the menstrual period, the catamenia sometimes appear, and sometimes are absent; if they appear, their duration is generally less than usual. The fact that conception often takes place immediately *before* the last appearance of the catamenia (and not *after* it, as commonly imagined), is one well known to practical men.—Numerous cases have been collected by Mr. Girdwood, Dr. Robert Lee, MM. Gendrin, Negrier, Raciborski, and others, in which the menstrual period was evidently connected with the maturation and discharge of ova; but the most complete observations yet made upon this subject, are those of Dr. Ritchie (loc. cit.). He states that about the period of puberty a marked change usually takes place in the mode in which the ovisacs discharge their contents; but that this change does not necessarily occur simultaneously with the first appearance of the catamenia; as in some cases, the conditions which obtain in the period before puberty, are extended into that of menstruation. The ovaries now receive a much larger supply of blood; and the ovisacs show a great increase in bulk and vascularity; so that, when they appear at the surface of the ovary, they present themselves as pisiform turgid elevations; and the discharge of their contents leaves a much larger cicatrix, and is accompanied by an effusion of blood into their cavity, with other subsequent changes, to be presently described. It would appear, however, that although such a discharge takes place *most frequently* at the menstrual period, yet that the two occurrences are not necessarily coexistent; for menstruation may take place without any such rupture; whilst, on the other hand, the maturation and discharge of mature ova may occur in the intervals of menstruation, and even at periods of life when that function is not taking place. Perhaps the most correct general statement on the subject would be this: that there is a periodic return of Ovarian excitement, which *tends to* the maturation and extrusion of ovules, though it may not always reach that point; whilst there is also a periodic turgescence of the vessels of the lining membrane of the Uterus, which *tends to* the production of a decidual membrane;—but that these two periods, though usually coincident, are not necessarily so; and that either change *may* occur without the concurrence of the other.

967. The duration of the period of aptitude for procreation, as marked by the persistence of the Catamenia, is more limited in Women than in Men, usually terminating at about the 45th year; it is sometimes prolonged, however, for ten or even fifteen years further; but cases are rare in

* "Sur la Ponte des Mammifères," Paris, 1844.

which women above 50 years of age have borne children. There is usually no menstrual flow during pregnancy and lactation; in fact, the cessation of the catamenia is generally one of the first signs, indicating that conception has taken place. But it is by no means uncommon for them to appear once or twice subsequently to conception; and in some women, there is a regular monthly discharge, though probably not of the usual secretion, through the whole period. Some very anomalous cases are on record, in which the catamenia never appeared at any other time than during pregnancy; and were then regular. The absence of the catamenia during lactation is by no means constant, especially if the period be prolonged; when the menstrual discharge recurs, it may be considered as indicating an aptitude for conception; and it is well known that, although pregnancy seldom recurs during the continuance of lactation, the rule is by no means invariable.

968. The function of the Female, during the coitus, is essentially passive. When the sexual feeling is strongly excited, there is a considerable degree of turgescence in the erectile tissue surrounding the vagina, and composing the greater part of the nymphæ and the clitoris; and there is an increased secretion from various glandular follicles.* But these changes are by no means necessary for effectual coition; since it is a fact well established, that fruitful intercourse may take place, when the female is in a state of narcotism, of somnambulism, or even of profound ordinary sleep. It has been supposed by some, that the os uteri dilates, by a kind of reflex action, to receive the semen; but of this there is no evidence. The introduction of a small quantity of the fluid just within the vagina, appears to be all that is absolutely necessary for conception;

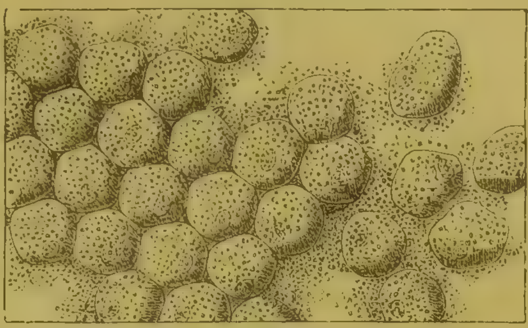
* The glands of Duverney have been very accurately described by Professor Tiedemann (1840), his attention having been directed to those organs by the late Dr. Fricke, of Hamburg. These glands are situated at either side of the entrance of the vagina, beneath the integument covering the inferior part of the vagina, as well as the superficial perineal fascia, and the constrictor vaginæ muscle. The space they occupy lies between the lower end of the vagina, the ascending ramus of the ischium, the crus clitoridis, and the erector clitoridis muscle. Superiorly are the fibres of the levator ani which are attached to the ischium, and behind these are the transversi-perinei muscles. They are surrounded by very loose cellular tissue. They are rounded, but somewhat elongated, being flat and bean-shaped. Their long diameter is from 5 to 10 lines; their transverse diameter $2\frac{1}{2}$ to $4\frac{1}{4}$ lines, and they are from $2\frac{1}{4}$ to 3 lines thick. Their excretory duct is at the anterior edge of the superior part of the gland, and runs beneath the constrictor vaginæ, horizontally forwards and inwards, to the inner face of the nympha, opening in front of the carunculæ myrtiformes, in the midst of a number of small mucous follicles. These glands were first discovered by Duverney in the cow, about the middle of the seventeenth century. Bartholinus subsequently found them in the human female, and his observations were confirmed by Duverney, Morgagni, Santorini, Peyer, &c. Haller denied their existence; and their presence seems to have been forgotten until they were again described by Mr. Taylor ("Dublin Journal," vol. xiii. 1838). They are analogous to Cowper's glands in the male, according to Tiedemann, and like them are sometimes wanting, and differ in size. In advanced age they are said to diminish in size, and even to disappear. They are present in the females of all animals, where Cowper's glands exist in the males. They secrete a thick, tenacious, greyish-white fluid, which is emitted in large quantity at the termination of the sexual act, most likely from the spasmodic contraction of the constrictor vaginæ muscle, under which they lie. Its admixture with the male semen has been supposed to have some connection with impregnation; but no proof whatever has been given that any such admixture is necessary. It seems not improbable, however, that it may serve, like the prostatic fluid of the male, to give a *dilution* to the seminal fluid that is favourable to its action. These glands were probably known to the ancients, and it is doubtless their secretion which Hippocrates and others describe as the female semen.— These glands have been since described by M. Huguier, in the "Archives d'Anatomie," (1847). His description corresponds in every respect with that given above.

for there are many cases on record, in which pregnancy has occurred, in spite of the closure of the entrance to the vagina by a strong membrane, in which but a very small aperture existed. That the spermatozoa make their way towards the ovarium, and fecundate the ovum either before it entirely quits the ovisac or very shortly afterwards, appears to be the general rule in regard to the Mammalia; and the question naturally arises,—by what means do they arrive there. It has been supposed that the action of the cilia which line the Fallopian tubes, might account for their transit; but the direction of this is *from* the ovaria towards the uterus, and would therefore be opposed to it. A peristaltic action of the Fallopian tubes themselves may generally be noticed in animals killed soon after sexual intercourse; and in those which have a two-horned membranous uterus, such as is evidently but a dilatation of the Fallopian tube, this partakes of the same movement, as may be well seen in the Rabbit; but this peristaltic action, like the ciliary movement, is *from* instead of towards the ovaries. Among the tribes whose ova are fertilized out of the body, the power of movement inherent in the spermatozoa is obviously the means by which they are brought in contact with the ova; and it does not seem unreasonable to suppose that the same is the case in regard to the higher classes, and that the transit of these curious particles, from the vagina towards the ovaries, is effected by the same kind of action as that which causes them to traverse the field of the microscope.—We shall now consider the changes in the Ovum and its appendages, by which it is prepared for fecundation.

969. Up to the period when the Ovum is nearly brought to maturity, it remains in the centre of the ovisac or inner layer of the Graafian follicle; and it is supported in its place by the 'membrana granulosa,' which is continuous with its proligerous disk. The movement of the ovum towards the surface, which has been already referred-to as a part of the changes by which it is prepared for fecundation, appears from the observations of Valentin to be due to the following cause. In the immature ovisac, the space between its inner layer and the ovum is for the most part filled-up with cells; these, however, gradually dissolve away, especially on the side nearest the surface of the ovary; whilst an albuminous fluid is effused from the deeper part of the ovisac, which pushes the residual layer (forming the discus proligerus) before it, and thus carries it against the opposite wall. At the same time, there is a gradual thinning-away of the various envelopes of the Graafian follicle, as well as of its own walls, in the situation of its most projecting part; and thus it is preparing to give way at that point, for the discharge of the contained ovum. Before rupture takes place, however, the ovisac itself undergoes a considerable change. Its walls become more vascular externally, and are thickened on their interior by the deposit of a fleshy-looking substance, which, in many of the lower Mammalia, is of a reddish colour, whilst in the Human female it is rather of yellowish hue. This substance is at first entirely composed of an aggregation of cells (Fig. 155), and may, in fact, be considered as an increased development, or hypertrophy, of the 'membrana granulosa' or epithelial lining of the ovisac. In domestic quadrupeds, this growth, which sprouts like a mass of granulations from the lining of the ovisac, is often so abundant, if the ovum be impregnated, as not only to fill the cavity of the ruptured vesicle, but even to protrude from the orifice on the surface of the ovary; this orifice,

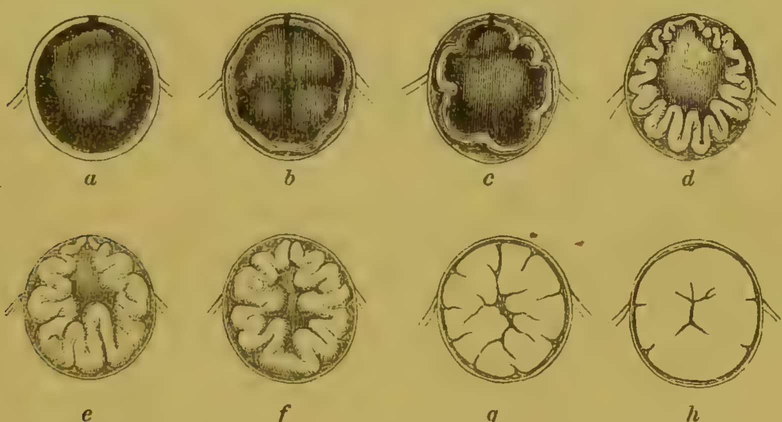
however, subsequently closes; and the contained growth becomes gradually firmer, its colour changing from red to yellow. In the Human female, however, the new formation consequent upon impregnation is less abundant; it does not form mamillary projections from the interior of the ovisac, but lies as a uniform layer upon its lining; and this is thrown into wrinkles or folds, in consequence of the contraction of the ovisac (Fig. 155 A, *a—d*). An irregular cavity is thus at first left in the interior of the ovisac, after the discharge of the ovum; but this gradually diminishes, partly in consequence of the increased growth of the yellow substance, and partly owing to the general contraction of the ovisac, until it is at last nearly obliterated or reduced to a sort of stellate cicatrix (*e—h*). An effusion of blood frequently takes place into this cavity, in the Human female, at the time of the rupture

FIG. 155.



Cells forming the original substance of the *Corpus Luteum.*

FIG. 155 A.




Successive stages of the formation of the *Corpus Luteum*, in the Graafian follicle of the Sow, as seen in vertical section;—at *a* is shown the state of the follicle immediately after the expulsion of the ovum, its cavity being filled with blood, and no ostensible increase of its epithelial lining having yet taken place; at *b*, a thickening of this lining has become apparent; at *c*, it begins to present folds which are deepened at *d*, and the clot of blood is absorbed *pari passu*, and at the same time decolorized; a continuance of the same process, as shown at *e*, *f*, *g*, *h*, forms the complete Corpus Luteum, with its stellate cicatrix.

of the ovisac; but the coagulum which is left takes no share in the formation of the yellow body. It generally loses its colouring matter, and acquires the characters of a fibrinous clot; and this may either form a sort of membranous sac, lining the cavity; or it may become a solid mass, occupying the centre of the stellate cicatrix.*

970. The cells which line the Graafian follicle undergo a great increase of size at the time of the discharge of the ovule, and are also partially metamorphosed into fibres, especially where they come into apposition with the enveloping wall of the follicle; in fact, a gradual transition may be traced between the cellular substance of the interior of the follicle, and the fibrous stroma of the Ovarium itself. In this manner is formed that

* This process was first accurately described by M. Pouchet, in his "Théorie Positive de l'Ovulation Spontanée," 1847.

reddish-yellow granulation-like substance, friable in consistence, and very vascular, which occupies that part of the ovary of a pregnant female whence the ovum has been discharged, and is known under the name of the *Corpus Luteum.* Its size varies according to the length of time which has elapsed since conception. At first, it is usually so large as to occasion a considerable projection on the surface of the ovary; its form is oval, or resembles that of a bean. When cut across, its dimensions are usually found to be from 4 to 5-8ths of an inch in its long diameter, and from 3 to 4-8ths in its short; and it thus occupies from a fourth to a half of the whole area of the ovarium; but these dimensions are not unfrequently exceeded. The centre of this substance is hollow; and by a proper acquaintance with this character, the true Corpus Luteum may be distinguished from substances bearing a general resemblance to it, but very different in their character. The following is Dr. Montgomery's account of it. "Its centre exhibits either a cavity, or a radiated or branching white line, according to the period at which the examination is made. If within the first three or four months after conception, we shall, I believe, always find the cavity still existing, and of such a size as to be capable of containing a grain of wheat at least, and very often of much greater dimensions; this cavity is surrounded by a strong white cyst; and as gestation proceeds, the opposite parts of this cyst approximate, and at length close together, by which the cavity is completely obliterated, and in its place there remains an irregular white line, whose form is best expressed by calling it radiated or stelliform. This is visible as long as any distinct trace of the corpus luteum remains." * The true corpus luteum is further distinguished by its capability of being injected from the vessels of the ovary; which is not the case with tubercular deposits, or other substances which may simulate it. After delivery, the size of the corpus luteum rapidly diminishes; and in a few months it ceases to be recognizable as such. The cicatrix by which the ovum has escaped is visible for some time longer; but this, too, according to the careful researches of Dr. Montgomery, cannot be distinguished at a subsequent period. Hence there is no correspondence between the number of corpora lutea found in the ovaries of a woman, or of cicatrices on their surface, and the number of children she may have borne. The number of corpora lutea must always be less, when there have been many conceptions, in consequence of the complete disappearance of some of them; but the number of cicatrices may be greater; for several causes, such as the escape of unimpregnated ova, or the bursting of little abscesses, may give rise to such appearances.

971. It is a question of much scientific interest, and one that occasionally becomes of importance in Juridical investigations, what extent of resemblance may exist between the condition of the Ovisac after the expulsion of an ovum that does *not* become impregnated, and that of a pregnant female in which a true 'corpus luteum' is present. This question cannot be decided by observations on domesticated quadrupeds; since it appears certain that in them there is altogether a more abundant production of the yellow substance than in the Human female, and that it is more persistent after the discharge of the ovum; which may perhaps be accounted-for by the greater functional activity or excitement

* "Signs of Pregnancy," p. 226.

f the ovarian apparatus in an animal "in heat," than usually exists in ıe Human female at the menstrual period. There is reason, moreover, ) believe that the amount of this may vary considerably in different ·males, and in the same female at different times. The general fact ɜrtainly is, that a thin layer of yellow substance, composed chiefly of ells and of fibres originating in the metamorphosis of cells, is ordinarily ɔrmed on the lining of the ovisac; that this is greatly increased in ıickness, if the ovum be impregnated; but that if it be not, it gradually isappears; so that, from this difference in the subsequent changes which may be probably attributed to the increased determination of lood to the whole Generative apparatus when it is in a state of excessive ınctional activity), the corpus luteum which is characteristic of the regnant state is usually a much larger and more highly organized body, han that which is commonly found in the ovary of the unimpregnated ɜmale. But it is also unquestionable that an unusual development of the bro-cellular substance may sometimes take place without impregnation; vhilst on the other hand, the changes which usually follow impregnation ıay take place so much less characteristically than usual, that the corpus ıteum, even at an early period of pregnancy, may be no larger than hat which is often found where pregnancy has not occurred. These ariations, which seem mainly to depend upon differences in the degree f vascular excitement of the ovaries, accompanying and succeeding the xtrusion of ova, render it impossible to draw any definite line of demarcation, by which we may at once determine what are, and what are not, he results of conception; but the following practical rules, deduced from consideration of all the circumstances yet known, may be laid down for he guidance of those who find it desirable to have some standard of ıdgment. — "1. A Corpus Luteum, in its earliest stage (that is, a large esicle filled with coagulated blood, having a ruptured orifice, and a thin ıyer of yellow matter in its walls), affords no proof of impregnation aving taken place. — 2. From the presence of a Corpus Luteum, the pening of which is closed, and the cavity reduced or obliterated, only a tellate cicatrix remaining, also no conclusion as to pregnancy having xisted or fecundation having occurred can be drawn, if the corpus ıteum be of small size, not containing as much yellow substance as vould form a mass the size of a small pea.—3. A similar Corpus Luteum f larger size than a common pea, would be strong presumptive evidence, ot only of impregnation having taken place, but of pregnancy having xisted during several weeks at least; and the evidence would approximate more and more to complete proof, in proportion as the size of the orpus luteum was greater." *

972. It cannot now be doubted, that the maturation and discharge of va from the Ovaries, is, in the Human female, and in Mammalia in eneral, an operation quite as independent of conception, and even of exual intercourse, as it is in those animals in which the ova are fertilized ut of the body;† and it is no longer considered essential, therefore, that

* See Dr. Baly's "Supplement to Müller's Physiology," p. 57; where a comprehensive ccount will be found of all the recent researches bearing upon this question.

† Two cases, in which Ovules, or their remains, were discovered in the Fallopian tubes of Vomen who had died during the Menstrual period, under circumstances which entirely recluded the idea of previous sexual intercourse, have been lately recorded by Dr. Letheby "Phil. Trans.," 1852, p. 57).

the seminal fluid should reach the ovarium in order to effect the fertilization of the ova, since this end may be answered by the contact of the two in the Fallopian tubes, or even in the Uterus itself. From the experiments of Bischoff, however, it appears that in rabbits, bitches, and probably in most other Mammalia, sexual union usually takes place previously to the escape of the ova from the ovary, and that sufficient time often elapses for the seminal fluid to reach the ovary before their extrusion occurs: in such cases, therefore, it would seem probable that fecundation is effected at the ovary itself. That such occasionally happens in the Human female, seems to be unequivocally proved by the occurrence of tubal or even of ovarian fœtation; the ovum having received the fertilizing influence immediately upon quitting the ovisac, or even before it has entirely extricated itself from the ovary, and having been in some way checked in its transit towards the uterus, so that its development has taken place in the spot at which it has been arrested. It is affirmed by Bischoff that by the time the ovum reaches the uterus, or even the lower end of the Fallopian tube, its capacity for impregnation is lost; but this assertion chiefly rests on the cessation of sexual desire, observed in those animals in which, after death, it was found that the ova had passed into the uterus, or had arrived at the lower part of the Fallopian tube. There is every reason to believe that this is not the case in the Human female; for, although the sexual desire may be the strongest about the period of the maturation and escape of the ova, yet it is by no means wanting at other times; and the occasional occurrence of cases in which impregnation has taken place from a single coitus in the middle of the interval between the menstrual periods, shows either that the ovum may retain its capacity for impregnation for some time after its escape from the ovary, or that its maturation and extrusion are not by any means invariably coincident with the menstrual period.*—The ova, when set free from the ovaries by the rupture of the ovisacs and the giving-way of their several envelopes, are received by the fimbriated extremities of the Fallopian tubes, which, during the period of sexual excitement, appear to be closely applied to the surface of the ovaries. Their conveyance along the Fallopian tubes is probably due in part to their peristaltic movement, and in part to the action of the cilia which clothe their internal surface.

973. The object of the changes which have been already described, is to bring the Ovum within reach of the fecundating influence, and to convey it into the uterus after it has been fertilized: we have now to consider the changes in the Ovum itself, which take place during the same epoch. At about the same period that the ovum moves towards the periphery of the Graafian follicle, the germinal vesicle moves towards the periphery of the yolk; and it always takes up its position at the precise point of the zona pellucida which is nearest the ovisac, and which is closest, therefore, to the surface of the ovary. Moreover, the germinal

* See a case of this kind recorded by Dr. Oldham in the "Medical Gazette," July 13, 1849.—Instances are certainly not unfrequent, in which conception has taken place five or six days after the conclusion of the menstrual period; the Author has himself known one in which this occurred, after the menstrual flow itself had persisted for a week. It has been urged that the known fertility of the Jewish females, who abstain from sexual intercourse for eight days, or even thirteen days, after the termination of the catamenia, is opposed to the idea that the menstrual period is that of 'heat'; but there is reason to believe that this is to be accounted-for in another way—namely, by the usual occurrence of conception from intercourse immediately *before* the access of the catamenia. (See Mr. Girdwood, in the "Lancet," Dec. 14, 1844.)

ot is always on that part of the germinal vesicle, which is in closest ntact with the zona pellucida. Thus, the germinal spot is very near the terior of the ovary; but is separated from it by the peritoneal coat of e latter, by a thin layer of its stroma forming the external layer of the raafian follicle, by the ovisac forming its internal membrane, and by the na pellucida. As soon as these give way, there is nothing to prevent e spermatozoa from coming into direct contact with the ovum, even efore it quits the ovisac. That such contact is an essential condition of cundation, there is every reason to believe; although, as to the precise anner in which it operates, we are at present in the dark. There can e no doubt that it is in the contact of the spermatozoa with the ovum, nd in the changes which occur as the immediate consequence of that ontact, that the act of Fecundation essentially consists. We have already en that the Spermatozoa constitute the essential part of the Seminal fluid § 959); and although it has been ascertained by Mr. Newport, that the permatic fluid as secreted by the testes is inferior in fertilizing power to hat which has been mingled with the prostatic fluid, yet it seems that this feriority simply results from its state of too great concentration, and not om any endowments peculiar to the prostatic fluid, since dilution with ther fluids answers the same purpose. Mr. Newport's most recent obser-ations upon the process of impregnation in the Frog (which the Author, hrough the kindness of Mr. N., has had the opportunity of verifying), how that the spermatozoa become imbedded in the gelatinous envelope f the ovum, within a few seconds after they come into contact with it, nd that they are thus brought into close approximation with (if they do ot absolutely pass through) the vitelline membrane; in this situation hey probably undergo a gradual diffluence; and thus the product of the sperm-cell' may be absorbed into the 'germ-cell,' and may intermingle ith its contents, just as in the fecundation of the ovule of Flowering-lants; the Spermatozoon being nothing else than an embodiment of the rtilizing material developed within the sperm-cell, which is endowed ith a temporary power of movement in order that it may find its way the Ovum. It has been remarked by Mr. Newport, that Sperma-zoa whose spontaneous *motility* has ceased, no longer possess the fecun-ating power; and this fact concurs with other phenomena to indicate, at it is not only a certain *material*, but a *vital force* of which that aterial is (so to speak) the vehicle, which is required to effect this most nportant operation.

974. The precise share which the Germinal Vesicle and Germinal Spot erform in the changes which take place in the ovum about the period f fecundation, has not yet been satisfactorily determined. According to r. Barry, the germinal vesicle becomes filled with a new development of ells, which sprout, as it were, from its nucleus (the germinal spot); and fter fecundation a pair of cells is seen in the space previously occupied y the pellucid centre of the nucleus, which is developed at the expense f the rest, and is the true foundation of the embryonic structure. This iew is to a certain extent confirmed by the observations of Wagner on he ova both of Frogs and Mammalia, and by those of Vogt on those of he Rana obstetricans; both of which lead to the belief that such a pro-ess of cell-formation does take place within the germinal vesicle, but that, istead of the further development being carried-on within the germinal esicle, as maintained by Dr. Barry, this ruptures and sets free the cells

that had been developed in its interior, which are now dispersed through the yolk, whose ulterior changes take place under their influence. Mr. Newport's view is nearly the same as this; and he states that, in the Frog, this dissolution of the germinal vesicle and diffusion of its contents takes place as a preparation for fecundation, and not in consequence of it.* That the germinal vesicle is no longer to be seen when the metamorphoses of the yolk have commenced, is now universally admitted; but with regard to the antecedent process just described, there is still a want of accordance amongst Embryologists, its existence being altogether denied by Bischoff, who maintains that the germinal vesicle simply dissolves away shortly after coition, as had been supposed by Dr. Barry's predecessors. The Author is strongly inclined to believe, however, from his own observations, as well as from *à priori* considerations, based on the history of Vegetable fertilization, that there *is* a development of cells within the germinal vesicle, at the time of its maturation; and that it is by the influence of the spermatic fluid upon one of these cells, after it has been set free in the midst of the yolk by the rupture or diffluence of the germinal vesicle, that the first cell of the embryonic fabric is generated.

975. Whatever be the precise nature and history of the Fecundating process, there can be no doubt that the properties of the germ depend upon conditions, both material and dynamical, supplied by *both* parents. This is most obviously shown by the *fusion* of the characters of the parents, which is exhibited by hybrids between distinct species or strongly-marked varieties among the lower animals, such as the Horse and Ass, the Lion and Tiger, or the various breeds of Dogs; or in the offspring of parents belonging to two strongly-contrasted Races of Men, such as the European on the one hand, and the Negro or American Indian on the other. But it is rare to meet with instances, even when the differences between the parents are far less strongly marked, in which some distinctive traits of both may not be readily traced; these traits showing themselves in peculiarities of manner and gesture, in tendencies of thought or feeling, in proneness to particular constitutional disorders, &c., even where there is no personal resemblance, and where there has been no possibility that these peculiarities should have been gained by imitation. And it is well known, too, that such peculiarities will often re-appear in a subsequent generation, after being apparently extinct; as if the agency which produced them had been overpowered for a time by some stronger influence, but had subsequently been left free to operate. This phenomenon is known as *atavism.*—The influence of particular perversions of the regular nutritive operations, brought about by causes to which the parents have been exposed, is often manifested in the offspring; thus we find gout, scrofula, syphilis, &c., hereditarily transmitted; and the children of habitual drunkards are distinguished by their tendency to Idiocy and Insanity.†—There seems good reason to believe, moreover, that the attributes of the germ are in great degree dependent, not merely upon the *habitual* conditions of the parents which have furnished its original components, but even upon the condition in which those parents may be at the time of sexual congress. Of this we have a remarkable proof in the phenomenon well known to breeders of animals, that a strong mental impression

* "Philosophical Transactions," 1851, p. 178.

† See the Author's "Prize Essay on Alcoholic Liquors," § 36; and Dr. Howe's "Report on Idiocy in Massachusetts," in Amer. Journ. of Med. Sci., April, 1849.

made upon the female by a particular male, will give the offspring a resemblance to him, even though she has had no sexual intercourse with him; a circumstance for which there is no difficulty in accounting, on the hypothesis already put forth regarding the dynamical relation of Mental states to the Organic processes (§ 945). And there is no improbability, therefore, in the idea that the offspring of parents ordinarily healthy and temperate, but begotten in a fit of intoxication on both sides, would be likely to suffer permanently from the abrogation of the reason, which they have temporarily brought upon themselves.* There is another class of facts which seems referable to the same category, that, namely, which exhibits the influence of a male parent upon the subsequent offspring of a different parentage; as in the well-known case of the transmission of the Quagga-marks to a succession of colts both whose parents were of the species Horse, the mare having been once impregnated by the Quagga male;† and in the not infrequent occurrence of a similar phenomenon in the Human species, as when a widow who marries a second time bears children strongly resembling her first husband. Some of these cases appear referable to the strong mental impression left by the first male parent upon the female; but there are others which seem to render it more likely that the blood of the female has imbibed from that of the fœtus, through the placental circulation, some of the attributes which the latter has derived from its male parent; and that the female may communicate these, with those proper to herself, to the subsequent offspring of a different male parentage.‡—On the whole, then, we seem entitled to conclude, that the attributes of the embryo will be influenced in a most important degree by the entire condition (as relates both to the organic and the psychical life) of both parents at the time of the sexual congress; and it is probably on account of the perpetual changes taking place in the bodily and mental state of each individual (his condition at any one time being the general resultant of all those changes), that we almost constantly witness marked differences between children born at successive intervals, however strong may be the 'family likeness' among them; whilst the resemblance between twins is almost invariably much closer.§

976. Having thus noticed the principal points of the history of the development and impregnation of the ovum, we shall proceed to consider the provisions made for the Nutrition of the Embryo, through the generative apparatus of the female, up to the time of parturition; deferring the history of the development of the germs for that separate consideration which the importance of that subject demands.—About the time that the ovum is leaving the ovary, the cells of the proligerous disk which immediately surrounds the zona pellucida become club-shaped; their small ends being applied to the surface of the ovum, so as to give it somewhat of a stellate appearance. According to Bischoff, these cells entirely disappear from the ovum of the rabbit, as soon as it has entered

* See a case of this kind related by Mr. G. Combe in the "Phrenological Journal," vol. viii. p. 471.

† "Philosophical Transactions," 1821.

‡ See an interesting discussion of this question, by Dr. Alex. Harvey, in the "Edinb. Monthly Journ," Oct., 1849, and Oct. and Nov., 1850; and in his pamphlet "On a Remarkable Effect of Cross-breeding," Edinb., 1851.

§ This strong resemblance, it is true, is occasionally deficient; but this may perhaps be fairly attributed to the circumstance of the twins being the offspring of different conceptions, which is undoubtedly sometimes the case, as is shown by the long interval that elapses between their births (§ 990).

the Fallopian tube: whilst in the bitch they become round, and continue to invest the ovum in this form throughout its whole transit to the uterus. During its passage, the ovum acquires a sort of gelatinous envelope, which is inclosed in a membrane of fibrous texture, termed the *Chorion.* This envelope is probably of an *albuminous* nature in reality, corresponding with the *white* of the Bird's egg; whilst the fibrous texture of the chorion seems to be produced, like the membranous basis of the egg-shell of the bird,* by the exudation of fibrin from the lining membrane of the Fallopian tube or oviduct. The outer layer of this envelope, in the egg of the bird, is consolidated by the deposition of particles of carbonate of lime in its areolæ; and none of it undergoes any higher organization. The Chorion of the Mammal, on the other hand, subsequently undergoes changes of a much higher order; which adapt it for participating, to a most important degree, in the nutrition of the included embryo. The first of these changes consists in the extension of the surface of the membrane into a number of villous prolongations, at first composed entirely of cells, which give it a spongy or shaggy appearance (Plate I. Fig. 10, *f,f*). These serve as absorbing radicles, and form the channel through which the embryo is nourished by the fluids of the parent, until a more perfect communication is formed, in the manner to be presently explained.

977. We have now to speak of the changes in the Uterus, which take place in consequence of Conception, and which prepare it to receive the ovum. Of these the most important is the formation of the Membrana *Decidua,* so called from its being cast off at each parturition. This membrane has been usually supposed to be a new formation; and has been described as originating in coagulable lymph thrown out on the inner surface of the uterus, into which vessels are prolonged from the subjacent surface. It appears, however, from the researches of Dr. Sharpey and Prof. Weber,† that this is not the true account of it; and that the Decidua vera is really composed of the inner portion of the Mucous membrane itself, which undergoes a considerable change in its character. The Mucous membrane of the uterus possesses on its free surface, a tubular structure (Figs. 156, 157); not very unlike that which has been described as existing in the lining membrane of the stomach (§ 440). This tubular portion becomes thickened and increased in vascularity, within a short time after conception; and when the inner surface of a newly-impregnated Uterus is examined with a low magnifying power, the orifices of its tubes are very distinctly seen, being lined with a white epithelium. The blood-vessels form a very minute network, which extends in loops from the subjacent portion of the membrane. According to the observations of Prof. Goodsir,‡ the interfollicular spaces also are crowded with nucleated particles; and it is to the development of this interfollicular substance, as well as to the enlargement of the follicles themselves, and the copious development of epithelial cells in their interior, that the mucous membrane in this condition owes its increased thickness. This increased development appears to have reference in part to the temporary nutrition of the Ovum, and in part to the further evolution of the decidual substance itself in the formation of the Placenta. The cavity

* "Princ. of Phys., Gen. and Comp.," § 160.
† Müller's "Elements of Physiology," pp. 1574–1580.
‡ "Anatomical and Physiological Observations," chap. ix.

of the uterus shortly becomes filled with a fluid, evidently poured out from the follicles in its walls, and containing a large number of nucleated cells; and in this the villi of the chorion are imbedded, obviously for the purpose of deriving from it the materials required for the development of

Fig. 156.

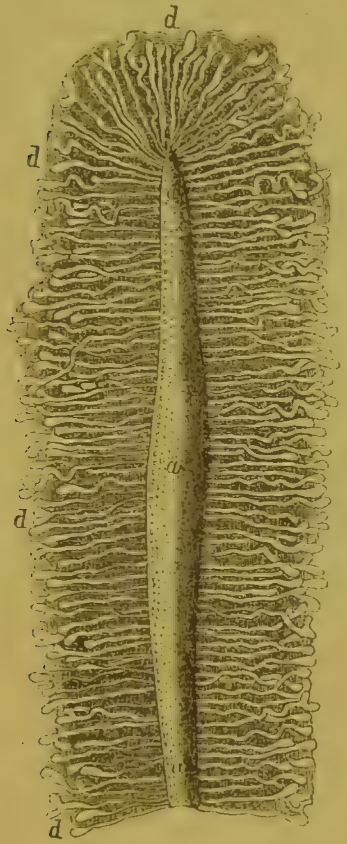



Fig. 157.

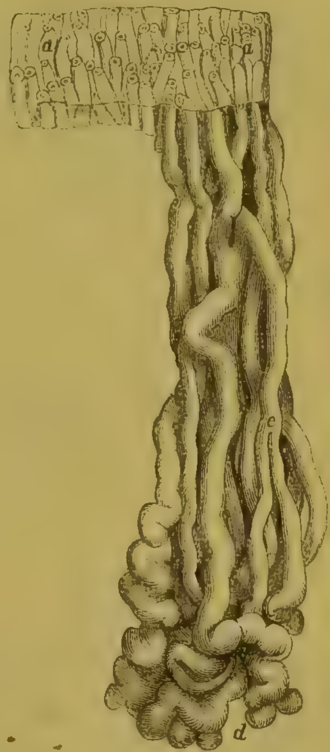



Fig. 156. Section of the *Lining Membrane of a Human Uterus* at the period of commencing pregnancy, twice the natural size; showing the arrangement and other peculiarities of the glands *d*, *d*, *d*, with their orifices, *a*, *a*, *a*, on the internal surface of the organ.
Fig. 157. A portion of Fig. 156 more enlarged, showing the convoluted extremities of the tubular glandulæ.

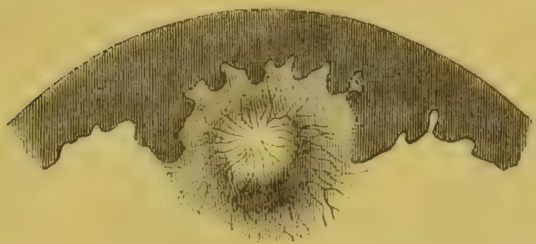
the embryonic structures. These villi are easily traced in the bitch (as Dr. Sharpey first pointed out) into the mouths of the uterine glandulæ, some of which are composite in their structure, a single outlet being common to a number of follicles; but they have not yet been so traced in the Human subject.

978. The Deciduous membrane is found at a later period to consist of two layers; the *Decidua vera* lining the uterus, and the *Decidua reflexa* covering the exterior of the ovum. Regarding the origin of this second layer, there has been a good deal of difference of opinion. The doctrine first propounded by Dr. W. Hunter, which is indicated by the name which he bestowed upon the membrane, was that the decidua reflexa is a portion of the true decidua, which has been pushed before the ovum at its entrance into the uterus; it being supposed that the true decidua forms a completely closed sac (like that of a serous membrane), against the *outside* of which the ovum is applied, so that it comes to be invested by a double layer of it, as the heart is by the pericardium, or the lungs by the pleura. But this view is negatived by a number of considerations.

3 T

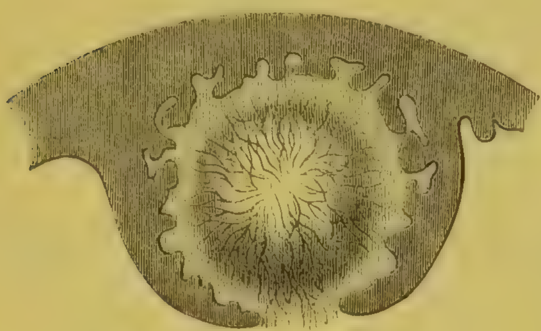
For, in the first place, the original decidua does not form the closed sac which this supposition involves, but extends (like the mucous membrane of which it is a metamorphosed form) into the Fallopian tubes; and the ovum, at its entrance into the uterus, really lies upon its internal surface. But again, the texture of the two layers is very different; for, as was first pointed-out by Prof. Goodsir (loc. cit.), the decidua reflexa is almost entirely composed of cells, exhibiting few or none of the orifices of the glandular follicles which are characteristic of the decidua vera, except near the part where the two layers are continuous. According to the observations of M. Coste, however, there is a considerable resemblance between the two layers at an early period; and he considers the following to be the mode in which the second investment is formed. When the ovum enters the uterus, it becomes partially imbedded in the substance of the decidua, which is as yet quite soft (Fig. 158); and this, receiving an increased nutrition at the part with which the ovum comes into contact, grows-up around it, very much after the manner in which the fleshy granulations grow-up around the pea imbedded in a caustic issue. This extension of the decidual substance continues (Fig. 159), until it has completely enveloped the ovum; and it is thus, according to him, that the decidua reflexa is formed, in continuity with the decidua vera.* As the ovum increases in size, the cavity between the decidua vera and the decidua reflexa gradually diminishes; and by the end of the 3rd month the two layers come into contact, and are henceforth scarcely or not at all distinguishable.

Fig. 158.



First stage of the formation of the *Decidua reflexa* around the Ovum.

Fig. 159.



More advanced stage of the same.

979. The surface of the Ovum, thus surrounded by the double layer of the deciduous membrane, is rendered shaggy by the growth of villous tufts from the surface of its investing chorion (Plate I. Fig. 10,*f*,*f*). Each of these tufts, as was first pointed-out by Prof. Goodsir,† is composed of an

* This doctrine was first announced by M. Coste, in a communication to the Parisian Academy of Sciences, on the basis of observations on two Uteri at the 20th and 25th days of gestation. (See "Comptes Rendus," Mai 24, 1847.) It seems to be altogether that which is most in harmony with observed facts; and especially with those which have been noticed by Professors Weber and Sharpey.—See, also, the Memoir of M. Robin, on the Mucous Membrane of the Uterus, in the "Archiv. Gén. de Méd.," 4e Ser., tom. xvii. xviii.

† "Anatomical and Pathological Observations," chap. ix.

assemblage of nucleated cells, which are found in various stages of development; and these are always enclosed within a layer of basement-membrane, which seems to be itself composed of flattened cells united by their edges. At the free extremity of each villus is a bulbous expansion, the cells composing which are arranged round a central spot; and it is at this point that the most active processes of growth take place, the villus elongating by the development of new cells from its germinal spot, and (like the spongiole of the plant) drawing-in nutriment from the soil in which it is imbedded. — In its earliest grade of development, the chorion and its villi contain no vessels; and the fluid drawn-in by the tufts is communicated to the embryo, by the absorbing powers of the germinal membrane of the latter. But when the tufts are penetrated by blood-vessels, and their communication with the embryo becomes more direct, the means by which they communicate with the parent are found to be still essentially the same; namely, a double layer of nucleated cells, one layer belonging to the fœtal tuft, and the other to the vascular maternal surface. It is from these elements that the *Placenta* is formed, in the manner next to be described.

980. The first stage in this process consists in the extension of the fœtal vessels into the villi of the Chorion over its entire surface, in the manner hereafter to be detailed (§ 1001); so that the nutriment which these villi imbibe, instead of being merely added to the albuminous fluid surrounding the yolk-bag, is now conveyed directly to the embryo. This — the earliest and simplest mode by which the Fœtus effects a new connection with the parent — is the only one in which it ever takes place in the lower Mammalia, which are hence properly designated as 'non-placental,' rather than as ovo-viviparous. In the higher Mammalia, however, there soon occurs a great extension of the vascular tufts of the fœtal chorion, at certain points; and a corresponding adaptation, on the part of the uterine structure, to afford them an increased supply of nutritious fluid. These specially-prolonged portions are scattered, in the Ruminantia and some other Mammalia, over the whole surface of the chorion, forming what are termed the 'cotyledons;' but in the higher orders, and in Man, they are concentrated in one spot, forming the Placenta. In some of the lower tribes, the maternal and the fœtal portions of the placenta may be very easily separated; the former consisting of the thickened decidua; and the latter being composed of the prolonged and ramifying vascular tufts of the chorion, dipping-down into it. But in the Human placenta, the two elements are mingled together through its whole substance.— On looking at the fœtal surface of the Human placenta, we perceive that the umbilical vessels diverge in every direction from the point at which they enter it; and their subdivisions form a large mass of capillaries, arranged in a peculiar manner,

FIG. 160.

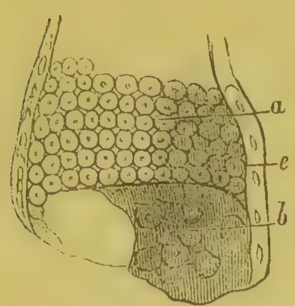
Portion of the ultimate ramifications of the Umbilical vessels, forming the *Fœtal Villi of the Placenta.*

(Fig. 160), and constituting what are known as the *fœtal villi.* Each villus contains one or more capillary loops, communicating with an artery on one side and with a vein on the other; but the same capillary may pass into several villi, before re-entering a larger vessel. The capillaries of the villi are covered, as in the chorion, by a layer of cells (Fig. 161, *f*), inclosed in basement-membrane (*e*); but the fœtal tuft thus formed is inclosed in a second series of envelopes (*a*, *b*, *c*), derived from the maternal portion of the placenta (Fig. 162),—a space (*d*) being left, however, between the two, at the extremity of the tuft.

Fig. 161.


Extremity of a *Placental Villus:*—*a*, external membrane of the villus, continuous with the lining membrane of the vascular system of the mother; *b*, external cells of the villus, belonging to the placental decidua; *c*, *c*, germinal centres of the external cells; *d*, the space between the maternal and fœtal portions of the villus; *e*, the internal membrane of the villus, continuous with the external membrane of the chorion; *f*, the internal cells of the villus, belonging to the chorion; *g*, the loop of umbilical vessels.

Fig. 162.




Portion of the external membrane, with the external cells, of a *Placental Villus:* —*a*, cells seen through the membrane; *b*, cells seen from within the villus; *e*, cells seen in profile along the edge of the villus.

981. Whilst the fœtal portion of the Placenta is thus being generated by the extension of the vascular tufts of the chorion, the maternal portion is formed by the enlargement of the vessels of the decidua, between which they dip-down. "These vessels assume the character of sinuses; and at last swell out (so to speak) around and between the villi; so that finally the villi are completely bound up or covered by the membrane which constitutes the walls of the vessels, this membrane following the contour of all the villi, and even passing to a certain extent over the branches and stems of the tufts. Between this membrane, or wall of the enlarged decidual vessels, and the internal membrane of the villi, there still remains a layer of the cells of the decidua." * In this manner is formed the maternal portion of the placenta, which may be regarded in its adult state (as was well pointed out by Dr. J. Reid †) in the light of a large sac formed by a prolongation of the inner coat of the uterine vessels; against the fœtal surface of which sac, the tufts just described may be said to push themselves, so as to dip-down into it, carrying before them a portion of its thin wall, which constitutes a sheath to each tuft. Now as every extension of the uterine vessels carries the decidua before it, every one of the vascular tufts that dips down into it will be covered with a layer of the cellular structure of the latter; and the fœtal portion of each tuft will thus be inclosed in a layer of *maternal* cells and basement-membrane (Fig. 161, *a*, *b*, *c*; and Fig. 162, *a*, *b*, *e*). In this manner, the whole interior of the placental cavity is intersected by numerous tufts of fœtal vessels, disposed in fringes, and bound down by reflections of the delicate membrane that

* Prof. Goodsir's "Anatomical and Pathological Observations," p. 60.

† "Edinb. Med. and Surg. Journ.," Jan. 1841; and "Anat., Phys., and Pathol. Researches,' chap. VIII.

forms its proper wall; just as the intestines are held in their places by the reflexions of the peritoneum that covers them. This view was suggested to Dr. R. by the very interesting fact, that the tufts of fœtal vessels not unfrequently extend beyond the uterine surface of the placenta, and dip-down into the uterine sinuses (Fig. 164); where they are still covered, and held in their places, by reflections of the same membrane. All the bands which connect and tie-down the tufts (Fig. 163, *g*), are formed of the same elements as the envelopes of the tufts themselves; namely, a fold of the lining membrane of the decidual sinuses, and a layer of the cellular decidua.

Fig. 163.

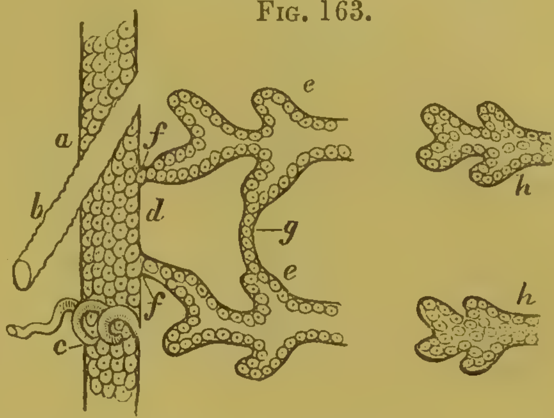



Diagram illustrating the arrangement of the *Placental Decidua*:—*a*, decidua in contact with the interior of the uterus; *b*, venous sinus passing obliquely through it by a valvular opening; *c*, a curling artery passing in the same direction; *d*, the lining membrane of the maternal vascular system, passing in from the artery and vein, lining the bag of the placenta, and covering *e*, *e*, the fœtal tufts, passing on to them from their stems from the fœtal side of the cavity, also by the terminal decidual bars *f*, *f*, from the uterine side, and from one tuft to the other by the lateral bar, *g*; *h*, *h*, separated fœtal tufts, showing the internal membrane and cells, which, with the loops of umbilical vessels, constitute the true fœtal portion of the tufts.

982. The blood is conveyed into the Placental cavity by the 'curling arteries' of the uterus (Fig. 164, *e*); and is returned from it by the large veins, that are commonly designated as sinuses (*b*, Fig. 164). The fœtal vessels, being bathed in this blood, as the branchiæ of aquatic animals are in the water that surrounds them, not only enable the fœtal blood to exchange its venous character for the arterial, by parting with its carbonic acid to the maternal blood, and receiving oxygen from it;

Fig. 164.


Diagram of the structure of the *Placenta;* showing *a*, the substance of the uterus; *b*, the cavity of a sinus; *c*, *c*, the fœtal tufts dipping-down into this; *d*, *d*, the decidual lining of the uterus; *e*, curling arteries.

but they also serve as rootlets, by which certain nutritious elements of the maternal blood (probably those composing the liquor sanguinis) are taken into the system of the fœtus. In this, they closely correspond with the villi of the intestinal canal; and there is this further very striking analogy,—that the nutrient material is selected and prepared by two sets of cells, one of which (the maternal) transmits it to the other

(the fœtal), in the same manner as the epithelial cells of the intestinal villi seem to take up and prepare the nutrient matter, which is destined to be still further assimilated by the cells that float in the circulating current (§ 461). It is probable, too, that the placenta is to be regarded as an excreting organ; serving for the removal, through the maternal blood, of excrementitious matter whose continued circulation through the blood of the fœtus would be prejudicial to the latter. And it will be in this mode that the blood of the mother may become impregnated with substances, or impressed with attributes, originally belonging to the male parent, so as to impart these to the products of subsequent conceptions by a different father (§ 975). There is no more direct communication between the mother and fœtus, than that which is afforded by this immersion of the fœtal tufts in the maternal blood; all the observations which have been supposed to prove the existence of real vascular continuity, having been falsified by the extravasation of fluid, probably consequent upon the force used in injecting the vessels. Moreover, the different size of the blood-corpuscles in the fœtus and in the parent (§ 149) shows the non-existence of any such communication.

983. The formation of the Placenta, in the manner just described, commences in the latter part of the second month; during the third, the organ acquires its proper character; and it subsequently goes on increasing in accordance with the growth of the ovum. Towards the end of the term of gestation, however, it becomes more dense and less vascular; owing, it would seem, to the obliteration of several of the minuter vessels, which are converted into hard fibrous filaments. The vessels of the uterus undergo great enlargement throughout, but especially at the part to which the placenta is attached; and the blood in moving through them produces a peculiar murmur, which is usually distinctly audible at an early period of pregnancy, and may be regarded (when due care is taken to avoid sources of fallacy), as one of its most unequivocal positive signs. The 'placental bruit' is thus described by Dr. Montgomery.* "The characters of this phenomenon are, a low murmuring or somewhat cooing sound, resembling that made by blowing gently over the lip of a wide-mouthed phial, and accompanied by a slight rushing noise, but without any sensation of impulse. The sound is, in its return, exactly synchronous with the pulse of the mother at the time of examination; and varies in the frequency of its repetitions, with any accidental variation which may occur in the maternal circulation. Its situation does not vary during the course of the same pregnancy; but in whatever region of the uterus it is first heard, it will in future be found, if recognized at all,—for it is liable to intermissions,—at least, we shall occasionally be unable to hear it where we have already heard it a short time before, and where we shall shortly again recognize it. According to my experience, it will be most frequently heard about the situation of the Fallopian tube of the right side; but it may be detected in any of the lateral or anterior parts of the uterus." That the cause of this sound exists in the Uterus itself, is distinctly proved by the fact, that it has been heard when that organ was so completely *anteverted*, that the fundus hung down between the patient's thighs. A sound so much resembling this, as to be scarcely

* "Signs of Pregnancy," p. 121.

distinguishable from it, may be occasioned, however, by a cause of a very different nature,—namely, an abdominal tumour, pressing upon the aorta, iliac arteries, or enlarged vessels of its own; and, in doubtful cases, it is necessary to give full weight to the possibility of such an explanation. The sound may be imitated at any time, by pressing the stethoscope on the iliac arteries. The placental bruit has been not unfrequently heard in the 11th week; but it cannot generally be detected before the fourth month, when the fundus uteri rises above the anterior wall of the pelvis.

984. The amount of the peculiar tissue of the Uterus (§ 305) greatly increases during pregnancy. At the same time, the Mammary gland and its appendages undergo a fuller development; and from this a valuable, but not unequivocal, indication of pregnancy may be drawn. Occasional shooting pains in the Mammæ are not unfrequently experienced within a short period after conception; and more continued tenderness is also not unusual. A sense of distension is very commonly experienced at about the end of the second month; and from that time a distinct "knottiness" usually begins to present itself, increasing with the advance of pregnancy. In many instances, however, these mammary sympathies are entirely absent; and they may be simulated by changes that take place in consequence of various affections of the uterus. A change of colour in the areola is a very common, but not an invariable, occurrence in the early months of pregnancy; but another sign is afforded by the areola and nipple, which is of more value because more constant,—namely, a puffy turgescence, and an increased development of the little glandular follicles, or tubercles, which commonly secrete a dewy moisture. —Many other changes in the constitution take place during pregnancy; indicated by the buffiness of the blood, the irritability of the stomach, and the increased excitability of the mind. All these, however, are discussed with sufficient amplification, in works on Obstetric Medicine.

985. The act of Conception, being one of a purely organic nature, is not itself productive of any sensation on the part of the mother; but there are some women in whom it is attended with certain sympathetic affections, such as faintness, vertigo, &c., that enable them to fix upon the particular time at which it has taken place. From that period, however, the mother has no direct consciousness of the change going on in the uterus (save by the effects of its increasing pressure on other parts), until the occurrence of what is termed 'quickening.' This is generally described as a kind of fluttering movement, attended with some degree of syncope or vertigo. After it has once occurred, and has strongly excited attention, it is occasionally renewed once or twice, and then gives place to the ordinary movements of the fœtus. Not unfrequently, however, no movement whatever is felt, until near the end of the term of gestation, or even through the whole of it. As to the cause of the sensation, Obstetricians are much divided; and no satisfactory account has been given of it. It has been vulgarly supposed to be due to the first movement of the fœtus, which was imagined then to become possessed of an independent life: and the English law recognizes the truth of this doctrine, in varying the punishment of an attempt to procure Abortion, according to whether the woman be 'quick with child' or not; and in delaying execution when a woman can be proved to be so, though it is made to proceed if she is not, even if she be unquestionably

pregnant. Whether or not the first *sensible* notions of the fœtus are the cause of the peculiar feeling in question, there can be no doubt that the embryo has as much independent vitality before, as after, the quickening. From the time that the ovum quits the ovary, it ceases to be a part of the parent, and is dependent on it only for a due supply of nourishment, which it converts, by its own inherent powers, into its proper fabric. This dependence cannot be said to cease at the moment of quickening; for the connection must be prolonged during several weeks, before the fœtus becomes capable of sustaining life without such assistance. The earliest period at which this may occur, will be presently considered (§ 990).

986. At the conclusion of about nine (solar) months from the period of conception, the time of Parturition arrives. In this act, the muscular walls of the uterus are primarily concerned; for a kind of peristaltic contraction takes place in them, the tendency of which is to press the contents of the cavity from the fundus towards the os uteri, and finally to expel them; and this contraction is alone sufficient to empty the uterus, when no impediment is presented to the exit of the fœtus, as we see in the occasional occurrence of *post-mortem* parturition. It is, in fact, in the contraction of the fibres of the fundus and body of the uterus, and in a relaxation of those about the cervix (which relaxation is something quite different from a mere yielding to pressure, and is obviously a vital phenomenon that marks a peculiarity in the actions of this part), that the first stage of an ordinary labour essentially consists. There is no proof whatever that these changes are dependent upon nervous influence; in fact, there is much evidence that the parturient action of the uterus is *not* the result (as some have maintained it to be) of a 'reflex' action of the Spinal Cord, but is due to its inherent contractility; for numerous instances have occurred, in which normal parturition has taken place, notwithstanding the destruction of the lower part of the Cord, or the existence of a state of complete paraplegia which marked its functional inactivity; and the continuance of the peristaltic action for some time after somatic death, when neither the Cerebro-spinal nor the Sympathetic system can afford any supply of nervous power, is yet a more satisfactory proof of the same position. Nevertheless, it seems quite certain that muscular contractions of the uterus *may be* induced by reflex action; for in no other way can we account for numerous phenomena, which distinctly mark the operation of remote causes acting through the nervous system, such as the induction of uterine contractions by the dash of cold water on the abdominal surface, by the injection of cold water into the vagina, by the ingestion of cold water into the stomach, or even by dipping the hands into cold water, or again by the suctorial application of the infant's lips to the nipple, by the introduction of the hand into the vagina, by violent movements of other parts of the body, and by various other means. This general fact has an important practical bearing; since there are various occasions on which it is most important to life, that the previously flaccid uterus should be excited to vigorous contraction, for the sake of accelerating parturition or of suppresing hæmorrhage; whilst, on the other hand, it is often no less important to be able to prevent or to antagonize the operation of causes which would prematurely induce uterine contractions, to the destruction of the offspring and

the danger of the mother.—When, in the normal act of Parturition, the head has so far made its way through the os uteri as to begin to distend the lower part of the genital canal, a new kind of expulsive effort is superadded to that of the uterus itself; the assistance of the Expiratory muscles being then called-in (§ 723), through the intermediation of the Spinal Cord, which is probably excited to this action by the stimulus thus applied to the afferent nerves of the compressed parts; and it is chiefly by the instrumentality of these muscles, that the normal act of parturition is usually completed. The same action which expels the fœtus, also detaches the placenta; and if the uterus contract with sufficient force after this has been thrown off, the orifices of the vessels which communicated with it are so effectually closed, that little or no hæmorrhage takes place. If, however, the uterus does not contract, or relaxes after having contracted, a large amount of blood may be lost in a short time from the open orifices. For some little time after parturition, a sero-sanguineous discharge, termed the *lochia*, is poured out from the uterus; and this commonly contains shreds of the deciduous membrane, which had not been previously detached, together with a quantity of fat-globules, and of other products of disintegration of the uterine tissue (§ 593).* Within a few weeks after delivery, the uterus regains (at least in a healthy subject) its previous condition; and it is probable that the portion of its mucous membrane which had been thrown off as Decidua, is very early reproduced.

987. As to the reason why the period of Parturition should be just nine months after the occurrence of Conception, we know nothing more than we do of that of similar *periodical* phenomena in the history of the life of Man and of other living beings; all of which must be considered as *occasional* manifestations of changes that are constantly in progress, whose rate, being dependent upon the degree of Heat supplied, is so uniform in warm-blooded animals, as to secure a very close conformity to a common standard.† There is evidence that the occurrence of the uterine *nisus* may be induced by a variety of causes, several of which probably concur in the normal act of Parturition. For, in the first place, the state of development of the muscular substance of the uterus can scarcely be without a considerable influence on this operation. We see it undergoing a gradual augmentation during the period of pregnancy, without any demand being made upon its functional activity; it gradually becomes more and more irritable, contractions being far more readily excited in it by electrical or other stimulation, in the later, than in the earlier months

* In addition to the evidence already cited, of the rapid occurrence of fatty degeneration of the uterine structure after parturition, the Author may mention that he has been informed by Dr. Retzius (Professor of Midwifery at Stockholm) that he has detected a large number of fat-globules in the urine of puerperal women. Is it not possible—it may be further asked—that some of the oleaginous matter so copiously poured forth by the mammary glands, may be derived from this source? Such an economy of nutrient material would be consistent with what we elsewhere meet with; and the idea is conformable to the fact, that the proportion of butyrine in the milk is much greater in the earlier, than in the later months of lactation.

† This may be best illustrated by the analogy of a Leyden jar which is being charged by the *continuous* action of an Electrical Machine, and which is so arranged as to *dis*charge itself spontaneously whenever the disturbance in its equilibrium attains a certain intensity. If the movement of the machine be uniform, and other conditions remain the same, the discharge will take place at regular intervals.

of pregnancy; and at last this irritability seems to reach its *acme*, in virtue of the nutritive changes which have been progressively taking place in it, and to discharge itself in one powerful effort.—That the parturient effort, however, is not solely dependent upon the state of development of the Uterus, appears from several considerations: and, in the first place, from the very curious fact that, in cases of Extra-uterine pregnancy, contractions resembling those of labour take place in its walls. Moreover, various states of the constitution, especially that which is designated as irritability, may induce the occurrence of the parturient efforts at an earlier period; and this constitutes Abortion, or Premature Delivery, according to the *viability* of the child. There are some women, in whom this regularly happens at a certain month, so that it seems to be an action natural to them; but it is always to be prevented, if possible, being injurious alike to the mother and the child; and this prevention is to be attempted by rest and tranquillity of mind and body, and by a careful avoidance of all the exciting causes which may produce uterine contractions by their operation on the Nervous system. Among the causes of Abortion, however, the death of the fœtus, or an abnormal state of the placental structure, is one of the most common; and thus we have a very distinct proof of the influence which the state of the *contents* of the uterus has on the induction of the parturient effort. In fact, what may be termed the *maturation* of the uterus and its contents,—a condition analogous to that which precedes the dropping of ripe fruit, and which is acquired by the completion of the developmental process,—appears to have more influence in determining the normal parturient effort, than any other cause which can be assigned. Certain preparatory changes are known to be taking place in the uterus itself during the last two or three weeks of gestation; for its upper part contracts itself more closely around its contents, as if it were bracing itself up for the coming encounter; whilst there is a greater disposition to relaxation of its lower part, as also in the soft parts surrounding the orifice of the pelvis, so that the whole mass descends. It is well known that there is far less aptitude for dilatation in the os uteri before this change takes place; so that premature labours are frequently rendered very difficult and tedious by the resistance which the fœtus encounters from the soft parts, notwithstanding that its smaller size enables it to pass more readily through the pelvic canal. The placenta of the fully-developed fœtus, again, is somewhat in the condition of the footstalk of a ripening fruit; that is, having attained its full evolution as an organ of temporary function, its connection tends to become dissevered in virtue of the further changes which take place in itself, quite irrespectively of any external agency.* This is very strikingly evinced by the fact, that when the uterus contains two fœtuses, and one of them is expelled,—either in consequence of impeded development or of disease in itself, or because it has attained its own full term of development (as in cases of superfœtation, § 990),—the other, if its development at this period is far from complete, is often retained, and goes on to its full term, *its* placenta not being detached in the first parturient effort, because it was

* Such a change may be easily verified in the placenta of many of the lower animals, such as the cat, in which the fœtal and maternal portions remain more distinct than they do in the human female; for these become far more easily separable from each other, as the period of parturition draws near, than they are at any previous time.

not then prepared for the separation. It is obvious that this view affords a rational explanation of the occurrence of uterine action in cases of extra-uterine fœtation; for, if the condition of the placental attachment furnish its exciting cause, it will do so equally, whether the placenta be attached to the lining of the uterus, or to that of the Fallopian tube, or to any other organ. It is an additional indication that the immediate stimulus to the parturient effort of the uterus is given by some change in the condition of its fœtal connexions, that the term of gestation seems capable of being prolonged by peculiarities in the constitution or rate of development of the fœtus, which are derived from the male parent; for it was ascertained by the late Earl Spencer,* that of 75 cows in calf by a particular bull, the average period was 288½ days, instead of 280; none of these having gone less than 281 days, and two-fifths of them having exceeded 289 days.†

988. Although the duration of Pregnancy is commonly stated at nine solar months, it would be more correct to fix the period at 40 weeks, or 280 days; which exceeds nine calendar months by from 5 to 7 days, according to the months included.‡ This, at least, is the average result of observation, in cases in which the period of Conception could be fixed, from peculiar circumstances, with something like certainty; but there can be no doubt that variations of a few days, more or less, are of continual occurrence. The period of Quickening may be relied on in some women, in whom it occurs with great regularity in a certain week of Pregnancy; but in general there is great latitude as to the time of its occurrence. The usual or average time is probably about the 18th week.

989. The question of the *extreme limit* of Gestation, is one of great importance both to the Practitioner and to the Medical Jurist; but it is one which cannot yet be regarded as satisfactorily decided. Many per-

* See Dr. J. C. Hall in "Medical Gazette," May 6, 1842.

† The very ingenious doctrine has been propounded by Dr. Tyler Smith ("Parturition, and the Principles and Practice of Obstetrics," London, 1849), that the exciting cause of parturition is to be found in the recurrence of the periodical excitement of the ovary, acting by reflexion on the uterus through the spinal system of nerves, the ovarian nerves being the *excitors* and the uterine the *motors;* this excitement continuing during the entire period of gestation, and giving a special tendency to abortion at each return; and acting with such potency at the eleventh recurrence as then to induce the parturient effort. He assigns no other cause, however, why this eleventh recurrence should be so much more effectual than the rest, than that by this time there is a much greater aptitude to contraction in the uterus itself, and an increased readiness to be thrown-off on the part of the placenta,—conditions which seem to the Author to be in themselves adequate to account for the result. Dr. Tyler Smith's hypothesis is distinctly negatived by the following facts:—1. The period of gestation, although *commonly* a multiple of the menstrual interval, is by no means *constantly* so; the former remaining normal when the latter is shorter or longer than usual. 2. Parturient efforts take place in the uterus, notwithstanding the previous removal of the lower part of the spinal cord. 3. The removal of the ovaries in the later part of gestation does not interpose the least check to the parturient action, as Prof. Simpson of Edinburgh has experimentally ascertained. The Author considers himself fully justified, therefore, in asserting that this hypothesis does not possess the slightest claim even to be entertained as a *possible* one; and would refer, for a more detailed examination of it, to the "Brit. and For. Med.-Chir. Review," vol. iv. p. 1.

‡ The mode of reckoning customary among women, is to date from the middle of the month after the last appearance of the Catamenia; but it is certain that Conception is much more likely to take place *soon* after they have ceased to flow, or even just before their access, than in the intervening period (§ 966); so that, in most instances, it would be most correct to expect labour at forty weeks and a few days after the last recurrence of the Menses.

sons, whose experience should give much weight to their opinion, maintain that the regular period of 40 weeks is never extended for more than two or three days; whilst, on the other hand, there are numerous cases on record, which, if testimony is to be believed at all (and in many of these, the character and circumstances of the parties place them above suspicion), furnish ample evidence, that Gestation may be prolonged for at least three weeks beyond the regular term.* The English law fixes no precise limit; and the decisions which have been given in our courts, when questions of this kind have been raised, have been mostly formed upon the collateral circumstances. The law of France provides that the legitimacy of a child born within 300 days after the death or departure of the husband shall not be questioned; and a child born after more than 300 days is not declared a bastard, but its legitimacy may be contested. By the Scotch law, a child is not declared a bastard, unless born after the tenth month from the death or departure of the husband.—Very important evidence on this subject is afforded by observations on the lower animals, which are free from those sources of fallacy which attend human testimony. The observations of Tessier, which were continued during a period of forty years, with every precaution against inaccuracy, have furnished a body of results which seems quite decisive. In the Cow, the ordinary period of gestation is about the same as in the Human female; but out of 577 individuals, no less than 20 calved beyond the 298th day, and of these, some went on to the 321st, making an excess of nearly six weeks. Of 447 Mares, whose natural period of gestation is about 335 days, 42 foaled between the 359th and the 419th days, the greatest protraction being thus 84 days, or just one-fourth of the usual term. Of 912 Sheep, whose natural period is about 151 days, 96 yeaned beyond the 153rd day; and of these, 7 went on until the 157th day, making an excess of 6 days. Of 161 Rabbits, whose natural period is about 30 days, no fewer than 25 littered between the 32nd and 35th; the greatest protraction was here one-sixth of the whole period, and the proportion in which there was a manifest prolongation was also nearly one-sixth of the total number of individuals. In the incubation of the common Hen, Tessier found that there was not unfrequently a prolongation to the amount of three days, or one-seventh of the whole period.—In regard to Cows, the observations of Tessier have been confirmed by those of Earl Spencer, who has published † a table of the period of gestation as observed in 764 individuals; he considers the average period to be 284 or 285 days; but no fewer than 310 calved after the 285th day; and of these, 3 went on to the 306th day, and 1 to the 313th. It is curious that, among the calves born between the 290th and 300th days, there was a decided preponderance of males,—these being 74 to 32 females; whilst all of those born after the 300th day were females. The additional series of observations subsequently made by Earl Spencer, in regard to the constant protraction of the period in 75 cows in calf by a particular bull, has been already noticed (§ 987).—Another series of observations has been published by Mr. C. N. Bement of Albany, U.S.,‡ who has

* A good collection of such cases will be found in Dr. Montgomery's excellent work on the "Signs of Pregnancy," and in Dr. A. Taylor's "Medical Jurisprudence."

† "Journal of the English Agricultural Society," 1839.

‡ "American Journal of the Medical Sciences," October, 1845.

recorded the period of gestation of 62 Cows. The longest period was 336 days; the shortest, 213 days. The average period for male calves was 288 days; and for females, 282 days.—On the whole, it may be considered, that in regard to the Human female, the French law is a very reasonable one; and there is quite sufficient analogical evidence to support the assertions of females of good character, having no motive to deceive, which lead to the conclusion that a protraction of at least four weeks is quite possible, and that a protraction to the extent of six weeks is scarcely to be denied.*

990. In regard to the *shortest* period at which Gestation may terminate, consistently with the viability of the Child, there is a still greater degree of uncertainty. Most practitioners are of opinion, that it is next to impossible for a fœtus to live and grow to maturity, which has not nearly completed its seventh month; but it is unquestionable that infants born at a much earlier period, have lived for some months, or even to adult age. It is rare in such cases, however, that the date of conception can be fixed with sufficient precision to enable a definite statement to be given. Of the importance of the question, a case which some time since occurred in Scotland affords sufficient proof. A vast amount of contradictory evidence was adduced on this trial; but, on the general rule of accepting positive in preference to negative testimony, it seems that we ought to consider it possible that a child may live for some months, which has been born at the conclusion of 24 weeks of gestation. In the case in question, the Presbytery decided in favour of the legitimacy of an infant born alive within 25 weeks after marriage.† A very interesting case is on record,‡ in which the mother (who had borne five children) was confident that her period of gestation was less than 19 weeks; the facts stated respecting the development of the child are necessarily very imperfect, as it was important to avoid exposing his body, in order that his temperature might be kept up; but at the age of three weeks, he was only 13 inches in length, and his weight was no more than 29 oz. At that time, he might be regarded, according to the calculation of the mother, as corresponding with an infant of 22 weeks or $5\frac{1}{2}$ months; but the length and weight were greater than is usual at that period, and he must have been probably born at about the 25th week. It is an interesting feature in this case, that the calorific power of the infant was so low, that artificial heat was constantly needed to sustain it; but that, under the influence of heat of the fire, he evidently became weaker, whilst the warmth of a person in bed rendered him lively and comparatively strong. During the first week, it was extremely difficult to get him to swallow; and it was nearly a month before he could suck. At the time of the report, he was four months old, and his health appeared very good.—Another case of very early viability has been more recently put on record by Mr. Dodd:§ in this, as in the former instance, the determination of the child's age rests chiefly on the opinion of the

* See especially two cases, 183 and 184, detailed by Dr. Murphy in his "Report of the Obstetric Practice of University College Hospital" for 1844; and another case since published by him in the "Medical Gazette" for 1849, vol. xlviii. p. 683.

† "Report of Proceedings against the Rev. Fergus Jardine," Edinburgh, 1839.

‡ "Edinb. Med. and Surg. Journal," vol. xi.

§ "Provincial Medical and Surgical Journal," vol. ii. p. 474.

mother; but there appears no reason for suspecting any fallacy. The child seems to have been born at the 26th or 27th week of gestation; and having been placed under judicious management, it has thriven well.—One of the most satisfactory cases on record, is that detailed by Dr. Outrepont* (Professor of Obstetrics at Wurtzburgh), and stated by Dr. Christison in his evidence on the case first alluded to. The evidence is as complete as it is possible to be in any case of the kind; being derived not only from the date assigned by the mother to her conception, but also from the structure and history of the child. The gestation could have only lasted 27 weeks, and was very probably less. The length of the child was 13½ inches, and its weight was 24 oz. Its development was altogether slow; and at the age of eleven years, the child seemed no more advanced in body or mind, than most other lads of seven years old. In this last point, there is a very striking correspondence with the results of other observations upon premature children, made at an earlier age. A very remarkable case has been since put on record by Dr. Barker of Dumfries,† in which the child is affirmed to have been born on the 158th day of gestation, or in the middle of the *twenty-third* week after intercourse. Its size, weight, and grade of development were conformable to the asserted period: for it weighed only 1lb. and measured 11 inches; it had only rudimentary nails, and scarcely any hair except a little of reddish colour on the back of the head; the eyelids were closed, and did not open until the second day; the skin was shrivelled. When born it was wrapped up in a box and placed before the fire. The child did not suck properly until after the lapse of a month, and did not walk until she was nineteen months old. Three years and a half afterwards, this child was in a thriving state, and very healthy, but of small make; she then weighed 29½lbs.

991. There is another question regarding the function of the Female in the Reproductive act, which is of great interest in a scientific point of view, and which may become of importance in Juridical inquiries;—namely, the possibility of *Superfœtation*, that is, of two distinct conceptions at an interval of greater or less duration; so that two fœtuses of different ages, the offspring perhaps of different parents, may exist in the uterus at the same time.—The simplest case of Superfœtation, the frequent occurrence of which places it beyond reasonable doubt, is that in which a female has intercourse on the same day with two males of different complexions, and bears twins at the full time; the two infants resembling the two parents respectively. Thus, in the slave-states of America, it is not uncommon for a black woman to bear at the same time a black and a mulatto child; the former being the offspring of her black husband, and the latter of her white paramour. The converse has occasionally, though less frequently, occurred: a white woman bearing at the same time a white and a mulatto child. There is no difficulty in accounting for such facts, when it is remembered that nothing has occurred to prevent the uterus and ovaria from being as ready for the second conception as for the first; since the orifice of the former is not yet closed up; and, at the time when one ovum is matured for fecundation, there are usually more in the same condition.—But it is not easy thus to

* "Henke's Zeitschrift," band vi.

† "Medical Times," Sept. 7, and Oct. 12, 1850.

account for the birth of two children, each apparently mature, at an interval of five or six months; since it might have been supposed that the uterus was so completely occupied with the first ovum, as not to allow of the transmission of the seminal fluid necessary for the fecundation of the second. In cases where two children have been *produced* at the same time, one of which was fully-formed, whilst the other was small and seemingly premature, there is no occasion whatever to imagine that the two were *conceived* at different periods; since the smaller fœtus may have been 'blighted,' and its development retarded, as not unfrequently happens in other cases. Nor is it necessary to infer the occurrence of Superfœtation in every case, in which a living child has been produced a month or two after the birth of another; since the latter may have been somewhat premature, whilst the former has been carried to the full term. But such a difference can scarcely be, at the most, more than $2\frac{1}{2}$ or 3 months; and there are several cases now on record, in which the interval was from 110 to 170 days, whilst neither of the children presented any indication of being otherwise than mature.*

### 4.—*Development of the Embryo.*

992. The history of the evolution of the germ, from its first appearance as *a single cell* lying in the midst of the yolk, to the time when it presents the form and structure characteristic of its parent-species, and is capable of maintaining an independent existence,—including the details of the progressive development of each separate organ and tissue, from its first appearance as an aggregation of simple cells formed by the duplicative subdivision of the primordial vesicle, to that stage of completeness in which it is able to bear a part in the vital economy of the new being,—and embracing, also, the succession of changes in the provisions for the nutrition of the embryo in the successive phases of its existence, and the adaptations of its general organization to each respectively,—constitutes one of the most interesting departments of Physiological Science, and one which has of late years received more attention than any other. It is a branch of the inquiry, however, which has, and seems likely to have, less *practical* bearing than any other; for neither as regards the preservation of the body in health, nor in its restoration from disease, is it easy to see what direct benefit the most exact knowledge of Embryonic Development is likely to afford. The chief subject on which it throws light, is that of Congenital Malformations and Deficiencies; many of which are now distinctly traceable to *arrest* or *irregularity* of the developmental processes, some of them, indeed, to *excess* (§ 596).—For these reasons, the topic before us will be passed-over much more lightly in the present Treatise, than its scientific importance might seem to demand; and all that will be here attempted, will be a mere sketch of the mode in which the evolution of the germ takes place, this being followed in the first instance as a whole, whilst its principal organs will be afterwards separately considered as they successively present themselves.

993. This sketch, however, will serve to convey an idea of the nature of the process, and to illustrate its conformity in Man to that great law of

* See the Article 'Superfœtation,' in Dr. Beck's "Elements of Medical Jurisprudence."

progress *from the general to the special,* which is equally manifested in the development of every other organized being. For, when we first discern the primordial cell which is to evolve itself into the Human organism, we can trace nothing that essentially distinguishes it from that which might give origin to *any* other form of organic structure, either Vegetable or Animal; its condition, in fact, being permanently represented by the humblest single-celled Plants and Animals. The earliest stage of its development consists in simple multiplication by duplicative subdivision, so that a mass of cells comes to be produced, amidst the several individuals of which no difference can be traced; and this also finds its parallel among the simpler organisms of both kingdoms. Soon, however, this *homogeneous* condition gives rise to a *heterogeneous* one; the further changes which different parts of the mass undergo, not being of the same uniform character, so that a marking-out of *organs,* or instrumental parts adapted for different purposes in the economy, comes to be discernible. The organs, however, whose distinctness first becomes apparent, are not usually those which we trace in the completed structure, but have a merely temporary character; being evolved either as a sort of scaffolding or frame-work for the building-up of the more permanent parts, or with a view to the nutrition of the embryo during the evolution of these. Although the first indications of heterogeneousness in the germinal mass are of nearly the same kind in all animals,—consisting in the formation of a *blastodermic membrane* (composed, however, of nothing else than layers of cells) upon its exterior, which serves as a sort of temporary stomach, whilst a large part of the included mass undergoes liquefaction, and serves as the nutrient material for the tissues which are to be evolved from it,—yet indications are very speedily manifested, of the *primary division* of the Animal Kingdom of which the new being is a member;—thus, in the case of the Human embryo, as of that of all Vertebrated animals, the first indication of the permanent organization is shown in the 'primitive trace' which marks out the line of the vertebral column (Plate II., Fig. 11); and in this we very soon discern the foundations of the separate vertebræ (Fig. 12, *c*). But there is nothing at this period to distinguish the germ of Man from that of *any other* Vertebrated animal, this early part of the developmental process being carried-on upon the same plan in every member of that sub-kingdom; and it is not until we meet with indications of the plans which are peculiar to the respective classes of that sub-kingdom, that we can discover whether the germ in course of evolution is to become a Mammal, Bird, Reptile, or Fish. So, even when it has been recognised as belonging to the Mammalian class, there is at first nothing to distinguish it from that of any other Mammal; and it is only with the advance of the developmental process, that indications successively present themselves, which enable us to distinguish, one after another, the characters of the order, the family, the genus, the species, the variety, the sex, and the individual,—*the more special features progressively evolving themselves out of the more general,* which is the expression of the law of development common to all Organized beings.*

* See, on this subject, the Author's "Princ. of Phys., Gen. and Comp.," CHAPS. VIII. and XVIII.; in the former of which will be found an examination of the commonly-received doctrine, that the higher forms in the course of their development pass through the phases which remain permanently characteristic of the lower.

994. With this progressive alteration in the condition of the embryo itself, a very remarkable series of alterations takes place, *pari passu*, in the mode in which it is supplied with nutrient material, and in the provisions for the aeration of its circulating fluid.—The first evolution of the germ takes place entirely at the expense of the *yolk;* of which, however, the store contained in the Mammalian ovum is very small. The whole of this is very speedily incorporated in the substance of the germ, by the peculiar process to be presently described; and there is no residual store of 'food-yolk,' such as that which, in the Bird, serves for the nutrition of the embryo during the whole remainder of the developmental process, being gradually absorbed into the substance of the blastodermic membrane, and there converted into blood. The Mammalian ovum, however, from the time it reaches the Uterus, is furnished with a new supply of nourishment, in the fluid secreted by the Decidual membrane (§ 977); and for the absorption of this, it is particularly adapted by the villosities which develope themselves from its own external envelope. These, at first entirely destitute of blood-vessels, are subsequently penetrated at a certain part of the surface, by the fœtal capillaries brought to them by an organ, the *Allantois*, which is developed in Birds as the temporary instrument of respiration; and thus is originated the *fœtal* portion of the Placenta, of whose formation details will be presently given. From the time that this organ is completed, up to the birth of the Infant, the embryo draws its nutrient materials direct from the maternal blood, though not receiving that blood *as such* into its own organism; and it is through the same medium that the aeration of its own blood is effected, its pulmonary apparatus being as yet inoperative. Its circulating system, arranged in accordance with these requirements, presents many peculiarities which mark its fœtal character; and the alteration in the course of the blood, which takes place as soon as the respiratory organs come into play, constitutes the essential difference between intra-uterine and extra-uterine life. If, as sometimes happens, the lungs of the new-born infant expand but imperfectly or scarcely at all, the circulation continues to be carried-on, in a greater or less degree, upon its intra-uterine plan; and this, when the placenta is no longer capable of supplying the needed aeration, is incompatible with the persistence of life.

995. Our knowledge of the first stages of the developmental process in the Mammalian ovum, is in many respects incomplete; and it is requisite to interpret what has been obscurely seen in the ova of this class, by the clearer views derived from observation of those of the lower animals.* —As already stated, the germinal vesicle disappears at or about the time of fecundation; but its disappearance is not a result of fecundation, since it also takes place in the unimpregnated egg, in consequence (it may be presumed) of the completion of its term of life, and of those operations which it was developed to perform. Its place is seen to be occupied, at an early period after fecundation, by a new and peculiar cell, the origin of which is obscure, but the destination of which is most

* The researches of Kölliker ("Müller's Archiv.," 1843, p. 68) and Bagge ("De Evolut. Strongyli et Ascarid., Diss. Inaug.," 1841) on the ova of Entozoa,—those of Mr. Newport ("Philos. Transact.," 1851) on the ova of Batrachia,—and those of Bischoff ("Entwickelungsgeschichte des Hunde-eies," 1845) on the ova of the Bitch,—are the most valuable which we at present possess.

important; for it is by the duplicative subdivision of this cell, first into 2, then into 4, then into 8, and so on, and by the metamorphoses which its progeny undergo, that the whole embryonic fabric is gradually evolved. Hence this cell may be termed the *embryo-cell.** At the same time a peculiar change begins to take place in the yolk, the whole sphere of which is first marked-out by a furrow into two hemispheres, and is at last completely divided by the extension of this fission to the centre; each half is again furrowed and then cleft in the same manner, and thus the entire yolk is broken-up into a mass of segments (Fig. 165). This 'segmentation' takes place *pari passu* with the multiplication of the embryo-cells, each of which is surrounded by a distinct portion of the yolk; and there seems every probability that it is determined by that multiplication, and that each cell of the pair that is formed by the duplicative subdivision of its predecessor, draws around itself its proper share of the nutritive material.—These changes take place, in the Mammalian Ovum, during its transit along the Fallopian tube to the uterus; so that, by the time of its arrival there, the whole cavity of the *Zona pellucida* is occupied by minute spherules of yolk, each containing a transparent vesicle,† the aggregation of which gives it a mulberry-like aspect (Fig. 166, A); and by a continuance of the same process of subdivision, the component segments becoming more and more minute, the mass comes to present a finely-granular aspect (B).

FIG. 165.


Progressive stages in the *Segmentation of the Yolk* of the Mammalian Ovum:—A, its first division into two halves; B, subdivision of each half into two; C, further subdivision, producing numerous segments.

996. At this stage it does not appear that the several segments of the yolk have a distinct enveloping membrane; but an envelope is now formed around each of them, converting it into a cell, of which the included vesicle constitutes the nucleus, and of which the portion of the yolk surrounding this forms the contents. This happens first to the peripheral portions of the mass; and as its cells are fully developed, they arrange themselves at the surface of the yolk into a kind of membrane,

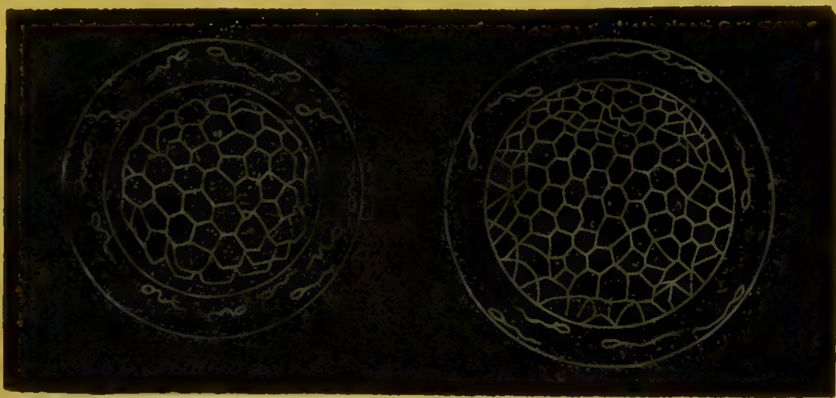
* The embryo-cell has not yet been clearly made out in the Mammalian ovum; but from the conformity of the subsequent appearances to those which are seen in the ova of the lower animals, there is every reason to believe that the formation of either a complete cell, or of a nucleus having the same essential endowments, is a preliminary to the cleavage of the yolk.

† This vesicle has not yet been made out, in the Mammalian ovum, to be a true cell, which it certainly is in the ovum of many of the lower animals; its appearance, when liberated from the yolk-granules which surround it, being rather that of a fat- or oil-globule.

and at the same time assume a pentagonal or hexagonal shape from mutual pressure, so as to resemble pavement-epithelium (Plate I. Fig. 5). As the globular masses of the interior are gradually converted into cells, they also pass to the surface and accumulate there, thus increasing the

Fig. 166.

A B



Latter stage in the *Segmentation of the Yolk* of the Mammalian Ovum; at A is shown the 'mulberry mass' formed by the minute subdivision of the vitelline spheres; at B, a further increase has brought its surface into contact with the vitelline membrane, against which the spherules are flattened.

thickness of the membrane already formed by the more superficial layer of cells, while the central part of the yolk remains, filled only with a clear fluid. By this means the exterior of the yolk is speedily converted into a kind of secondary vesicle, situated within the Zona pellucida, and named by Bischoff the *blastodermic vesicle.* This vesicle, very soon after its formation, presents at one point an opaque, roundish spot (Plate I. Fig. 6), which is produced by an accumulation of cells and nuclei of less transparency than elsewhere; this is termed the *area germinativa.* The wall of the vesicle, which is termed the *germinal membrane,* increases in extent and thickness, by the formation of new cells (whose mode of production has not been clearly made out); and it subdivides into two layers (Plate I. Fig. 7), which, although both at first composed of cells, soon present distinctive characters, and are concerned in very different ulterior operations. The outer one of these is commonly known as the *serous* layer (Fig. 8); but being the one in whose substance the foundation is laid for the vertebral column and the nervous system, it is sometimes called the *animal* layer. The inner one is usually known as the *mucous* layer (Fig. 9); and being the one chiefly concerned in the formation of the nutritive apparatus, it is sometimes called the *vegetative* layer. This division is at first most evident in the neighbourhood of the area germinativa; but it soon extends from this point, and implicates nearly the whole of the germinal membrane.

997. The Area Germinativa, at its first appearance, has a rounded form; but it soon loses this, becoming first oval, and then pear-shaped (Plate II. Fig. 11). While this change is taking place in it, there gradually appears in its centre a clear space, termed the *area pellucida* (*a*); and this is bounded externally by a more opaque circle (whose opacity is due to the greater accumulation of cells and nuclei in that part than in the area pellucida), which subsequently becomes the *area vasculosa.* In the formation of these two spaces, both the serous and mucous layers of

the germinal membrane seem to take their share; but the foundation of the embryonic structure, known as the *primitive trace*, is laid in the serous lamina only. This consists in a shallow groove (*c*), lying between two oval masses (*b*), known as the *laminæ dorsales*. The form of these changes with that of the area pellucida; at first they are oval, then pyriform, and at last become of a guitar-shape. At the same time, they rise more and more from the surface of the area pellucida, so as to form two ridges of higher elevation, with a deeper groove between them; and the summits of these ridges tend to approach each other, and gradually unite, so as to convert the groove into a tube. At the same time, the anterior portion of the groove dilates into three recesses or vesicles (Plate II. Fig. 12, *b*), which indicate the position of the three principal divisions of the Encephalon, afterwards to be developed as the *prosencephalon*, the *mesencephalon*, and the *epencephalon* (§ 1012). The most internal parts of these laminæ, bounding the bottom and sides of the groove, appear to furnish the rudiments of the nervous centres which this cranio-vertebral canal is to contain; whilst the outer parts are developed into the rudiments of the vertebral column and cranium. Even before the laminæ dorsales have closed over the primitive groove, a few square-shaped and at first indistinct plates, which are the rudiments of vertebræ (*c*), begin to appear at about the middle of each. The position of the bodies of the vertebræ is indicated at this period, in the embryos of Birds and Fishes, by a distinct cylindrical rod of nucleated cells, termed the *chorda dorsalis;* and this retains its embryonic type in the Myxinoid Fishes (§ 1010). While this is going on, an accumulation of cells takes place between the two laminæ of the germinal membrane at the 'area vasculosa;' and these cells speedily form themselves into a distinct layer, the *vascular* lamina, in which the first blood-vessels of the embryo are developed, as will be presently described (§ 998). From the dorsal laminæ on either side, a prolongation passes outwards and then downwards, forming what is known as the *ventral lamina;* in this are developed the ribs and the transverse processes of the vertebræ; and the two have the same tendency to meet on the median line, and thus to close-in the abdominal cavity, which the dorsal laminæ have to inclose the spinal cord. At the same time, the layers of the germinal membrane which lie beyond the extremities of the embryo, are folded-in, so as to make a depression on the yolk; and their folded margins gradually approach one another under the abdomen. The first rudiment of the intestinal canal presents itself as a channel along the under surface of the embryonic mass, formed by the rising-up of the inner layer of the germinal membrane into a ridge on either side. The two ridges gradually arch-over and meet, so as to form a tube, which is thus (so to speak) pinched-off the general vitelline sac; and it remains in connection with this, by means of an unclosed portion, which constitutes the 'vitelline duct' (Figs. 169, 170).

998. Whilst these new structures are being produced, a very remarkable change is taking place in that part of the serous lamina which surrounds the area pellucida. This rises up on either side in two folds; and these gradually approach one another, at last meeting in the space between the general envelope and the embryo, and thus forming an additional investment to the latter. As each fold contains two layers of membrane, a double envelope is thus formed; of this, the outer lamina

adheres to the general envelope; whilst the inner remains as a distinct sac, to which the name of *Amnion* is given. (See Figs. 168, 169, and 170.) This takes place during the third day in the Chick; the period at which it occurs in the Human Ovum is difficult to be ascertained,

FIG. 167.

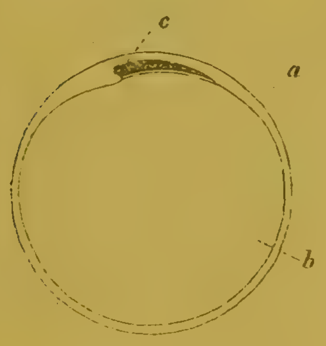



FIG. 168.

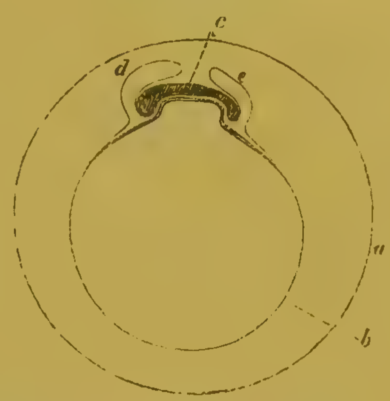



Fig. 167.—Plan of early Uterine Ovum. Within the external ring, or zona pellucida, are the serous lamina, *a*; the yolk, *b*; and the incipient embryo, *c*.

Fig. 168.—Diagram of Ovum at the commencement of the formation of the *Amnion*:—*a*, chorion; *b*, yolk-sac; *c*, embryo; *d*, and *e*, folds of the serous layer rising up to form the amnion.

owing to the small number of normal specimens which have come under observation at a sufficiently early stage.—During the same period, a very important provision for the future support of the embryo begins to be made, by the development of blood-vessels and the formation of blood. Hitherto, the embryonic structure has been nourished by direct absorption of the alimentary materials supplied to it by the yolk; but its increasing size, and the necessity for a more free communication between its parts than any structure consisting of cells alone can permit, call for the development of vessels through which the nutritious fluid may be conveyed. These vessels are first seen in that part of the Vascular lamina of the germinal membrane (§ 294), which immediately surrounds the embryo; and they form a network, bounded by a circular channel, which is known under the name of the *Vascular Area* (Plate II. Fig. 13). This gradually extends itself, until the vessels spread over the whole of the membrane that contains the yolk. The first blood-discs appear to be formed from the nuclei of the cells, whose cavities have become continuous with each other to form the vessels (§ 149); and from these, the subsequent blood-discs of the first series are probably generated. This network of blood-vessels serves the purposes of absorbing the nutritious matter of the yolk, and of conveying it towards the embryonic structures, which are now in process of rapid development. The first movement of the fluid is *towards* the embryo; and this can be witnessed before any distinct heart is evolved. The same process of absorption from the yolk, and of conversion into blood, probably continues as long as there is any alimentary material left in the sac.

999. The Yolk-sac is early separated in the Mammalia, by a constriction of the portion which is continuous with the abdomen of the Embryo; and it is known from that time under the name of the *Umbilical Vesicle* (Plate I. Fig. 10, *i*). The communication, however, remains open for a time through the vitelline duct; and even after this has been cut off, the trunks which connect the circulating system of the embryo with

that of the vascular area are discernible; these are called *Omphalo-Mesenteric*, *Meseraic*, or *Vitelline* vessels (Figs. 171, 172, *q*, *r*). It was formerly believed that the nutrient matter of the yolk passes directly through the vitelline duct, into the (future) digestive cavity of the embryo, and is from it absorbed into its structure; but there can now be little doubt, that the vitelline vessels are the real agents of its absorption, and that they convey it through the general circulating system, to the tissues in process of formation. They correspond, in fact, to the Mesenteric veins of Invertebrated animals, which are the sole agents in the absorption of nutriment from their digestive cavity (§ 459); and the blastodermic vesicle is to be regarded as the temporary stomach of the embryo,—remaining as the permanent stomach in the Radiated tribes.*

1000. The formation of the *Heart*, which is the first of the permanent organs of the Embryo that comes into functional activity, takes place in the substance of the vascular layer, beneath the upper part of the spinal column. Its first rudiment consists of an aggregation of cells, of which the inner part break-down to form its cavity, whilst the outer remain to constitute its walls. For a long time after it has distinctly commenced pulsating, and is obviously exerting a contractile force, its walls obviously retain the cellular character, and only become muscular by a progressive histological transformation (§ 310). The first appearance of the Heart in the Chick is at about the 27th hour; the time of its formation in Mammalia has not been distinctly ascertained. In its earliest form, it has the same simple character which is presented by the central impelling cavity of the lower Invertebrata; being a mere prolonged canal, which at its posterior extremity receives the veins, and at its anterior sends forth the arteries. After a short time, however, it becomes bent upon itself (Plate II. Fig. 13, *d*); and it is soon subdivided into three cavities, which exist in all Vertebrata, viz., a simple *auricle* or receiving cavity, a simple *ventricle* or propelling cavity, and a *bulbus arteriosus* at the origin of the aorta. The circulation is at first carried on exactly upon the plan which is permanently exhibited by Fishes. The Aorta subdivides into four or five arches on either side of the neck (Figs. 171, 172, *e*, *e'*, *e''*), which are separated by fissures much resembling those forming the entrances to the gill-cavities of Cartilaginous Fishes; and these arches re-unite to form the descending aorta, which transmits branches to all parts of the body.—Such is the first phase or aspect of the Circulating Apparatus, which is common to all Vertebrata during the earliest period of their development, and which may, therefore, be considered as its most

* Previously to the ninth day of incubation (in the Fowl's egg), a series of folds are formed by the lining membrane of the yolk-bag, which project into its cavity; these become gradually deeper and more crowded, as the bag diminishes in size by the absorption of its contents. The vitelline vessels that ramify upon the yolk-bag, send into these folds (or valvulæ conniventes) a series of inosculating loops, which immensely increase the extent of this absorbing apparatus. But these minute vessels are not in immediate contact with the yolk; for there intervenes between them (as was first noticed by Mr. Dalrymple) a layer of nucleated cells, which is easily washed away. (See Dr. Baly's Translation of "Müller's Physiology," pp. 1557-1559.) It was from the colour of these, communicated to the vessels beneath, that Haller termed the latter *vasa lutea;* when the layer is removed, the vessels present their usual colour. There seems good reason to believe that these cells, like those of the Intestinal Villi in the adult (§ 461), are the real agents in the process of absorbing and assimilating the nutritive matter of the yolk; and that they deliver this up to the vessels, by themselves undergoing rupture or dissolution, being replaced by new layers.

general form. It remains permanent in the class of Fishes; and in them the vascular system undergoes further development on the same type, a number of minute tufts being sent-forth from each of the arches, which enter the filaments of the gills, and serve for the aeration of the blood. In higher Vertebrata, however, the plan of the circulation is afterwards entirely changed, by the formation of new cavities in the heart, and by the production of new vessels; these changes will be presently described. It is incorrect, therefore, to speak of the vascular arches in *their* necks as *branchial* arches; since no branchiæ or gills are ever developed from them. The clefts between them may be very distinctly seen in the Human Fœtus towards the end of the first month; during the second, they usually close-up and disappear.

1001. With the evolution of a Circulating apparatus, adapted to absorb nourishment from the store prepared for the use of the Embryo, and to convey it to its different tissues, it becomes necessary that a Respiratory apparatus should also be provided, for depurating the blood from the carbonic acid with which it becomes charged during the course of its circulation. The temporary Respiratory apparatus now to be described, bears a strong resemblance in its own character, and especially in its vascular connections, to the gills of the Mollusca; which are prolongations of the external surface (usually near the termination of the intestinal canal), and which almost invariably receive their vessels from that part of the system. This apparatus, which is termed the *Allantois*, sprouts-forth from the caudal extremity of the embryo, at first as a little mass of cells, which soon exhibits a cavity (probably formed by the liquefaction of the cells of the internal part), so that a vesicle is formed (Figs. 169, 170, *g*), which looks like a diverticulum from the lower part

Fig. 169.

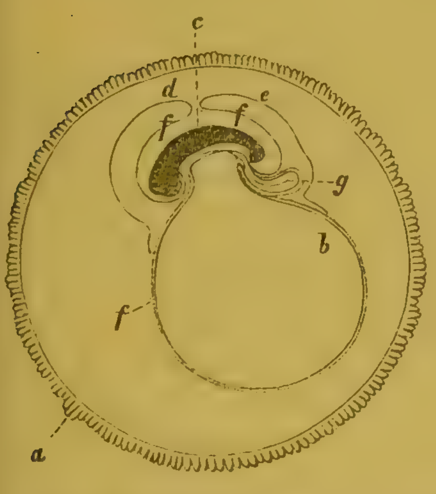



Fig. 170.

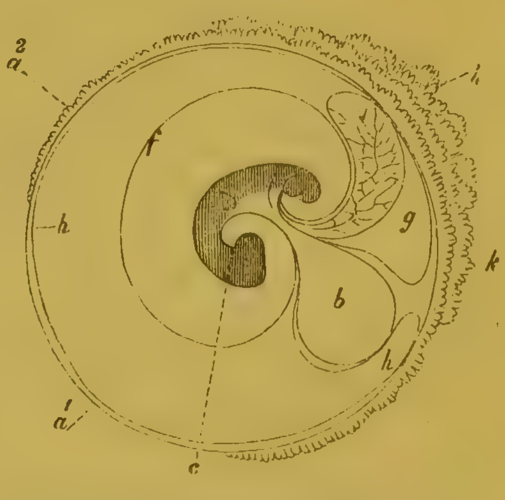



Fig. 169.—Diagram of an early *Human Ovum*, with the Amnion in process of formation :—*a*, the chorion; *b*, the vitelline mass, surrounded by the blastodermic vesicle; *c*, the embryo; *d*, *e*, and *f*, external and internal folds of the serous layer, forming the amnion; *g*, incipient allantois.

Fig. 170.—Diagram representing a *Human Ovum* in second month :—*a* 1, smooth portion of chorion; *a* 2, villous portion of chorion; *k*, *k*, elongated villi, beginning to collect into Placenta; *b*, vitelline or umbilical vesicle; *c*, embryo; *f*, amnion (inner layer); *g*, allantois; *h*, outer layer of amnion, coalescing with chorion.

of the digestive cavity. This vesicle, in Birds, soon becomes so large as to extend itself around the whole yolk-sac, intervening between it and the

membrane of the shell, and coming through the latter into relation with the external air; but in the embryos of Mammalia, being early superseded by another provision for the aeration of the blood, the allantois seldom attains any considerable dimensions. Its chief office in them is to convey the vessels of the embryo to the chorion; and its extent bears a pretty close correspondence with the extent of surface, through which the chorion comes into vascular connection with the decidua. Thus, in the Carnivora, whose placenta extends like a band around the whole ovum, the allantois also lines nearly the whole inner surface of the chorion; on the other hand, in Man and the Quadrumana, whose placenta is restricted to one spot, the allantois is small, and conveys the fœtal vessels to one portion only of the chorion. When these vessels have reached the chorion, they ramify in its substance, and send filaments into its villi; and in proportion as these villi form that connection with the uterine structure which has been already described (§§ 977–982), do the vessels increase in size. They then pass directly from the fœtus to the chorion; and the allantois, being no longer of any use, shrivels-up, and remains as a minute vesicle, only to be detected by careful examination. The same thing happens in regard to the umbilical vesicle, from which the entire contents have been by this time withdrawn; and from henceforth the fœtus is completely dependent for the materials of its growth upon the supply it receives through the placenta, which is conducted to it by the vessels of the umbilical cord. This state of things is represented in Figs. 171, 172, *n n'*, *o o'*.—The Allantois has a correspondence in origin with the Urinary Bladder; but it is only the lowest part of it, pinched off, as it were, from the rest, which remains as such. The duct by which it is connected with the abdomen gradually shrivels; and a vestige of this is permanent, forming the Urachus or suspensory ligament of the Bladder by which it is connected with the Umbilicus. Before this takes place, however, the Allantois is the receptacle for the secretion of the Corpora Wolffiana, and of the true Kidneys, when they are formed (§ 1007).

1002. It will be seen from the succeeding diagram, that the Umbilical Cord receives an investment from the Amnion, which forms a kind of tubular sheath around it; it is continuous at the umbilicus with the integument of the fœtus; and at the point where the cord enters the placenta, it is reflected over its internal or fœtal surface. The Amnion (which thus forms a shut sac, like that of the pleura, arachnoid, &c.) contains a fluid known as the *liquor amnii;* this consists of water holding in solution a small quantity of albumen and saline matter, and resembling, therefore, very diluted serum. During the first two months of gestation, the amnion and the inner lining of the chorion (which is really the reflected layer of the amnion, just as the lining of the abdominal cavity is formed by the peritoneum) are separated by a gelatinous-looking substance; which probably aids in the nutrition of the embryo, previously to the formation of the placenta. This is absorbed during the second month; and the amnion is then found immediately beneath the chorion. — In the Umbilical Cord, when it is completely formed, the following parts may be traced. 1. The tubular sheath afforded by the Amnion. 2. The Umbilical Vesicle (Fig. 171, *t*), with its pedicle, or vitelline duct. 3. The Vasa Omphalo-Meseraica (*q*, *r*), or mesenteric vessels of the embryo, by which the yolk was absorbed into

its body; these accompany the pedicle. 4. The Urachus, and remains of the Allantois. 5. The Vasa Umbilicalia (*nn*, *o*), which, in the later period of gestation, constitute the chief part of the Cord. These last vessels consist in Man of two arteries and one vein. The arteries are the main branches of the Hypogastric; and they convey to the placenta the

Fig. 171.

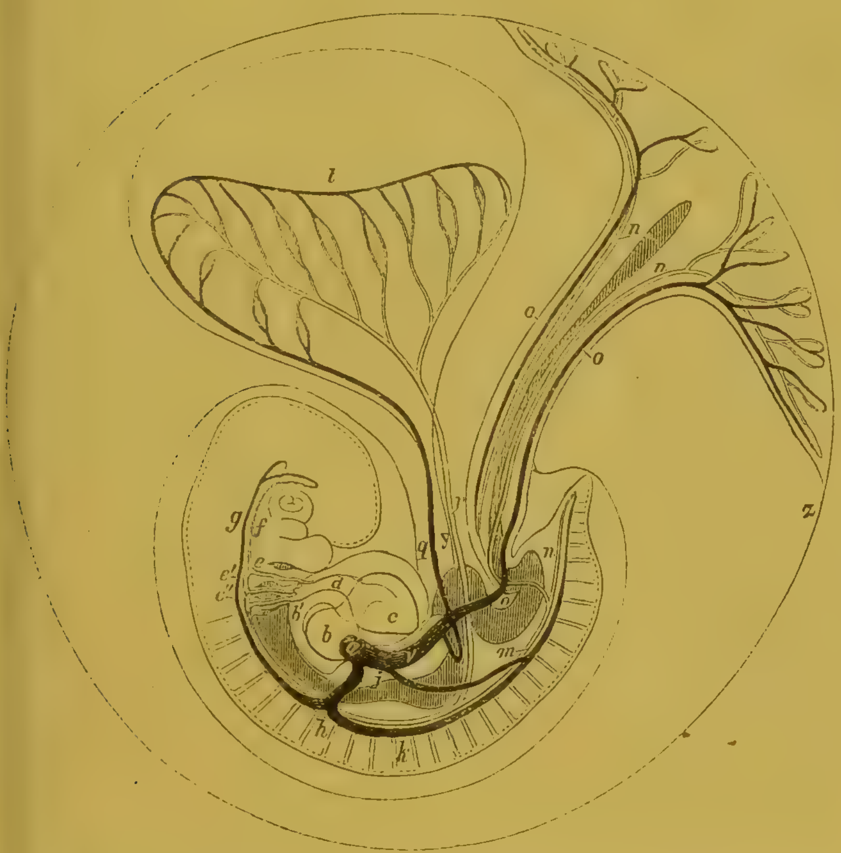


Fig. 172.

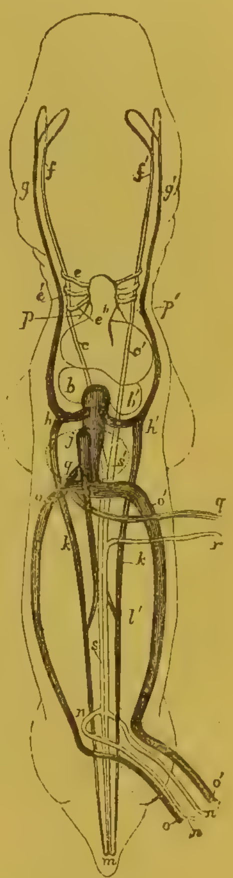


Fig. 171.—Diagram of the Circulation in the *Human Embryo* and its Appendages, as seen in profile from the right side, at the commencement of the formation of the Placenta:—*a*, venous sinus receiving all the systemic veins; *b*, right auricle; *b'*, left auricle; *c*, right ventricle; *d*, bulbus aorticus, subdividing into *e*, *e'*, *e''*, branchial arteries; *f*, arterial trunk formed by their confluence; *g*, vena azygos superior; *h*, confluence of the superior and inferior azygos; *j*, vena cava inferior; *k*, vena azygos inferior; *m*, descending aorta; *n*, *n*, umbilical arteries proceeding from it; *o*, umbilical vein; *q*, omphalo-mesenteric vein; *r*, omphalo-mesenteric artery, distributed on the walls of the vitelline vesicle *t*; *v*, ductus venosus; *y*, vitelline duct; *z*, chorion.
Fig. 172.—The same, as seen from the front.

blood which has to be aerated and otherwise revivified, by being brought into relation with that of the mother. The vein returns this to the fœtus, and discharges a part of it into the Vena Portæ, and a part directly through the Ductus Venosus into the Vena Cava.

1003. A change in the type of the Circulating system of the fœtus, from that at first presented by it (§ 1000), takes place at a very early period. At about the 4th week, in the Human Embryo, a septum begins to be formed in the ventricle; and by the end of the 8th week it is complete. The septum auriculorum is formed at a somewhat later period, and it remains incomplete during the whole of fœtal life; it is partly closed by the valvular fold covering the foramen ovale, which fold is developed in the 3rd month. During the same period, a transformation takes place in the arrangement of the large vessels proceeding from the heart; which ends in their assumption of the form they present until the end of

Fœtal life; and this undergoes but a slight alteration, when the plan of the circulation is changed at the moment of the first inspiration. The number of aortic arches on each side, which was five at first, soon becomes reduced in the Mammalia to three, by the obliteration of the two highest pairs. The 'bulbus aorticus' is subdivided, by the adhesion of its walls at opposite points, into two tubes, of which one becomes the Aorta and the other the Pulmonary Artery: and of the three pairs of (branchial) arches, the highest, being connected with the aortic trunk, contributes to the formation of the Subclavian and Carotid arteries; whilst of the middle pair, the arch on the right side is obliterated, and the other becomes the 'arch of the aorta.' The lowest pair arises from the Pulmonary trunk, and forms the right and left Pulmonary arteries; that on the left side, however, goes on to join the descending aorta as before, and thus constitutes the Ductus Arteriosus. A knowledge of these different stages in the development of the Heart and Arterial system enables us to explain many of the malformations which they occasionally present in Man; these being for the most part due to arrest of development, whereby the circulating apparatus is permanently fixed in conditions that are properly characteristic of cold-blooded animals. And it is interesting to remark, too, that the varieties which not unfrequently present themselves in the arrangement of the principal trunks given-off from the Aorta, find their analogues in the arrangements that are normally characteristic of some or other of the Mammalia.*—The Venous system undergoes changes which are even more remarkable than those of the arterial trunks. In its earliest condition, it has been ascertained by Rathke † to present essentially the same type in the embryoes of all Vertebrated animals, the peculiarities of each group being acquired by a process of subsequent transformation. There is at first a pair of anterior venous trunks (Figs. 170, 171, *g*, *g'*), receiving the blood from the head, and a pair of posterior trunks (*k*, *k'*), formed by the confluence of the veins of the trunk, Wolffian bodies, &c.; the former are persistent as the jugular veins; the latter remain separate in most Fishes, where they are designated the cardinal veins; but in Man (as in warm-blooded Vertebrata generally) they are only represented by the *venæ azygos*, major and minor,‡ which coalesce into a common trunk for a considerable part of their length. One of the anterior trunks and one of the posterior unite on either side, to form a canal which is known as the Ductus Cuvieri; and the ducts of the two sides coalesce to form a shorter main canal, which enters the auricle, at that time an undivided cavity. This common canal is absorbed into the auricle at an early period, in all Vertebrata above Fishes; and after the septum auriculorum is formed, the two Cuvierian ducts separately enter the right auricle. This arrangement is persistent in Birds and the inferior Mammals, in which we find two Venæ Cavæ superiores, entering the right auricle separately; but in the higher Mammalia and in Man, the left duct is obliterated and the right alone remains as the single Vena Cava superior, a transverse communicating branch being formed, to bring to it the blood of the left side.§ The double Vena

* See "Princ. of Phys., Gen. and Comp.," §§ 491, 492.
† "Ueber den Bau und die Entwickelung des Venensystems der Wirbelthiere," 1838.
‡ See Müller's "Verleichende Anatomie der Myxinoiden," Berlin, 1840.
§ The stages of this transformation have been particularly well made out by Mr. Marshall.

Cava sometimes presents itself as a monstrosity in the Human subject. As the anterior extremities are developed, the subclavian veins are formed to return the blood from them; and these discharge themselves into the jugulars. The Omphalo-Mesenteric vein (§ 999), which is another primitive trunk common to all Vertebrata, is formed by the confluence of the veins of the yolk-bag and intestinal canal, and passes by itself, with the two Cuvierian ducts, into the auricle. The upper part of this remains to constitute the upper part of the Inferior Cava (Figs. 171, 172, *j*), the lower portion of which arises between the Wolffian bodies, and originally enters the omphalo-mesenteric vein above the liver. When the liver is formed, the omphalo-mesenteric vein becomes connected with it both by afferent and by efferent trunks, the former remaining as the Vena Portæ, and the latter as the Hepatic vein; and after giving off the former trunks, the omphalo-mesenteric vein is itself obliterated, so that all the blood which it conveys passes through the liver. The Inferior Cava, which receives the hepatic vein, is gradually enlarged by the reception of most of the veins from the inferior part of the trunk and the lower extremities, and the vena azygos is reduced in the same proportion; in some rare cases of abnormal formation, however, the vena cava fails to be developed, and then the blood from the lower parts of the body is conveyed to the superior cava through the system of the vena azygos. The Umbilical Vein is to be regarded as a product of the combination of the veins of the allantois with an anterior vein of the abdominal parietes; it being probably through this latter channel that it comes to discharge itself into the vena portæ, which lies in a part of the body very distant from that at which the allantois was developed. As the omphalo-mesenteric vein diminishes in size, the umbilical vein increases, becoming the chief source of supply to the vena portæ; and it also forms an anastomosis with the inferior cava, which constitutes the Ductus Venosus.

1004. The following is the course of the Circulation in the mature Fœtus.—The fluid brought from the placenta by the umbilical vein is partly conveyed at once to the ascending Cava by means of the ductus venosus, and partly flows through the vena portæ into the Liver, whence it reaches the ascending Cava by the hepatic vein. Having thus been transmitted through the two great depurating organs, the Placenta and the fœtal Liver, it is in the condition of arterial blood; but, being mixed in the vessels with that which has been returned from the trunk and lower extremities, it loses this character in some degree, by the time that it arrives at the Heart. In the right auricle, which it then enters, it would be also mixed with the venous blood brought thither by the descending Cava; were it not that a very curious provision exists, to prevent (in great degree, if not entirely) any such further dilution. The Eustachian valve has been found, by the experiments of Dr. J. Reid,* to serve the purpose of directing the *arterial* blood, which flows upwards from the *ascending* Cava, through the foramen ovale, into the *left* auricle, whence it

in his elaborate Memoir 'On the Development of the Great Anterior Veins in Man and Mammalia' ("Phil. Trans.," 1850); and he has further shown that some vestiges of the original arrangement may be traced even in the normal condition of the venous system in the adult.

* "Edinb. Med. and Surg. Journal," vol. xliii.; and "Anat., Physiol., and Pathol. Researches," Chap. ix.

Fig. 173.


The *Fœtal Circulation*:—1. The umbilical cord consisting of the umbilical vein and two umbilical arteries; proceeding from the placenta (2). 3. The umbilical vein dividing into three branches; two (4, 4) to be distributed to the liver; and one (5), the ductus venosus, which enters the inferior vena cava (6). 7. The portal vein, returning the blood from the intestines, and uniting with the right hepatic branch. 8. The right auricle; the course of the blood is denoted by the arrow proceeding from 8, to 9, the left auricle. 10. The left ventricle; the blood following the arrow to the arch of the aorta (11), to be distributed through the branches given off by the arch to the head and upper extremities. The arrow 12 and 13, represent the return of the blood from the head and upper extremities through the jugular and subclavian veins, to the superior vena cava (14), to the right auricle (8), and in the course of the arrow through the right ventricle (15), to the pulmonary artery (16). 17. The ductus arteriosus, which appears to be a proper continuation of the pulmonary artery; the offsets at each side are the right and left pulmonary artery cut off; these are of extremely small size as compared with the ductus arteriosus. The ductus arteriosus joins the descending aorta (18, 18), which divides into the common iliacs, and these into the internal iliacs, which become the umbilical arteries (19) and return the blood along the umbilical cord to the placenta, and external iliacs (20), which are continued into the lower extremities. The arrows at the termination of these vessels mark the return of the venous blood by the veins to the inferior cava.

passes into the *left* ventricle; whilst it also directs the *venous* blood, that has been returned by the *descending* Cava, into the *right* ventricle. When the ventricles contract, the arterial blood which the left contains is propelled into the ascending Aorta, and supplies the branches that proceed to the head and upper extremities, before it undergoes any admixture; whilst the venous blood, contained in the right ventricle, is forced through the Pulmonary artery and Ductus Arteriosus into the descending Aorta, mingling with the arterial current which that vessel previously conveyed, and passing thus to the trunk and lower extremities. Hence the head and superior extremities, whose development is required to be in advance of that of the lower, are supplied with blood nearly as pure as that which returns from the placenta; whilst the rest of the body receives a mixture of this with what has previously circulated through the system; and of this mixture a portion is transmitted to the placenta, to be renovated by coming into relation with the maternal fluid. At birth, the course of the current is entirely changed by its diversion into the Lungs, which takes place immediately on the first inspiration. The Ductus Venosus and Ductus Arteriosus soon shrivel into ligaments; the Foramen Ovale becomes closed by its valve; and the circulation, which was before carried on upon the plan of that of the higher Reptiles, now becomes that of the complete Bird or Mammal. It is by no means unfrequent, however, for some arrest of development to prevent the completion of these changes; and various malformations, involving an imperfect discharge of the function, may hence result.

1005. The *Alimentary Canal* has been shown (§ 997) to have its origin ı the blastodermic vesicle; being a portion pinched off (as it were) from ıat part of it which is just eneath the spinal column f the embryo, whilst the emainder, which is at that ime the largest part of it, ɔrms the vitelline or umbiical vesicle. In its earliest ɔrm, it is merely a long ıarrow tube (Fig. 174, *m*), ıearly straight, and comaunicating with the umbiical vesicle (*n*, *n*) at about he middle of its length; hus it may be regarded as omposed of the union of wo divisions, an upper and . lower. At first, neither aouth nor anus exists; but hese are formed early in he second month, if not ›efore. The tube gradually aanifests a distinction into ts special parts, œsophagus, tomach, small intestine, nd large intestine; and he first change in its posi-

Fig. 174.

Embryo of *Dog*, 25 days after last copulation; — *a*, *a*, nostrils; *b*, *b*, eyes; *c*, *c*, first visceral arch, forming the lower jaw; *d*, *d*, second visceral arches; *e*, right auricle; *f*, left auricle; *g*, right ventricle; *h*, left ventricle; *i*, aortic bulb; *k*, *k*, liver, between the two lobes of which is seen the divided orifice of the omphalo-mesenteric vein; *l*, stomach; *m*, intestine, communicating with the umbilical vesicle *n*,*n*; *o*,*o*, corpora Wolffiana; *p*, allantois; *q*, *q*, anterior extremities; *r*, *r*, posterior extremities.

ion occurs in the stomach, which, from being disposed in the line ›f the body, takes an oblique direction. The curves of the large .nd small intestines present themselves at a later period. It is at the ower part of the small intestine, near its termination in the large, hat the entrance of the vitelline duct exists; and a remnant of this ;anal is not unfrequently preserved throughout life, in the form of a ;mall pouch or diverticulum from that part of the intestine. — In mmediate connection with the intestinal tube, we find the first rudinent of the *Liver*, which is formed by the thickening of the cells in the vall of the canal, at the spot at which the hepatic duct is subsequently .o discharge itself. This thickening increases, so as to form a projection ıpon the exterior of the canal; and soon afterwards the lining memɔrane of the intestine dips down into it, so that a kind of cæcum is 'ormed, surrounded by a mass of cells, as shown in Fig. 175. The in;rease of the organ seems to take place by a continual new budding-forth ›f cells from its peripheral portion; and a considerable mass is thus 'ormed, before the cæcum in its interior undergoes any extension by 'amifications into it. Gradually, however, the cells of the exterior become netamorphosed into fibrous tissue for the investment of the organ; those ›f the interior break down into ducts, which are developed in continuity vith the cæcum derived from the intestine, and which are lined by nuscular and fibrous tissues developed from the primitive cellular blas.ema; whilst those which occupy the intervening space, and which form

the bulk of the gland, give origin to the proper secreting cells, which are now to come into active operation. As this is going on, the hepatic mass is gradually removed to a distance from the wall of the alimentary canal; and the cæcum is narrowed and lengthened, so as to become a mere connecting pedicle, forming, in fact, the main trunk of the hepatic duct. In the Human embryo, the formation of the liver begins at about the third week of intra-uterine existence; the organ is from the first of very large size, when compared with that of the body; and between the third and the fifth weeks, it is one-half the weight of the entire embryo. It is at that period divided into several lobes. By the third lunar month, the liver extends nearly to the pelvis, and almost fills the abdomen; the right side now begins to gain upon the left; the gall-bladder begins to appear at this time. The subsequent changes chiefly consist in the consolidation of the viscus, and the diminution of its proportional size. Up to the period of birth, however, the bulk of the liver, relatively to that of the entire body, is much greater than in the adult; the proportion being as 1 to 18 or 20 in the new-born child, whilst it is about 1 to 36 in the adult; and the difference between the right and left sides is still inconsiderable. During the first year of extra-uterine life, however, a great change takes place; the right lobe increases a little or remains stationary, whilst the left lobe undergoes an absolute diminution, being reduced nearly one-half; and as, during the same period, the bulk of the rest of the body has been rapidly increasing, the proportion is much more reduced during that period, than in any subsequent one of the same length. According to Meckel, the liver of the newly-born infant weighs one-fourth heavier than that of a child of eight or ten months old; and as the weight of the whole body is more than doubled during the same time, it is obvious that the change in the proportion of the two must be principally effected at this epoch. The liver seems to be actively engaged, during fœtal life, in the depuration of the blood (as appears from the accumulation of meconium, which is chiefly altered bile, in the intestinal canal at birth), whilst at the same time it is serving as a blood-making organ (§ 150 *note*).—The general history which has just been given of the development of the Liver, seems equally applicable to the other glands that are evolved from the parietes of the Alimentary canal, such as the *Salivary glands* and *Pancreas;* since they all seem to commence in little masses of cells, formed by an increased development, at certain spots, of the layer of blastema which originally constitutes its wall; and whilst some of these cells give origin to the proper tissues of each gland, others form its ducts and tubuli by their deliquescence.

FIG. 175.


Origin of the *Liver* from the intestinal wall, in the embryo of the Fowl, on the fourth day of incubation:—*a*, heart; *b*, intestine; *c*, everted portion giving origin to liver; *d*, liver; *e*, portion of vitelline vesicle.

1006. The *Lungs* also are developed in immediate relation with the upper part of the Alimentary canal, their first rudiments shooting forth as a pair of bud-like processes (Fig. 176, *a*) from its œsophageal portion.

These were originally described by Von Bär as hollow, and as in reality *diverticula* from the tube itself. But most later observers agree in stating that the bud-like processes are not at first hollow, but are solid aggregations of cells, formed by a multiplication of the cells constituting the external wall of the alimentary tube, into which its internal tunic is not prolonged. These gradually increase in size, extending downwards by the multiplication of their component cells in that direction; and cavities are formed in them (probably, as in the preceding instances, by the deliquescence or fusion of some of the cells of their interior), which at first communicate with the pharynx by separate apertures; these, however, coalescing into one, as the channels are elongated into tubes, and the pulmonary organs are removed to a distance from their point of exit. This process commences, in the Chick, about the 4th day of incubation; and on the 5th or 6th, the lungs are completely detached from the œsophagus, and each has its own bronchial tube connecting it with the trachea common to both (Fig. 176, *b*). The upper portion of the lung has much thicker walls than the lower; and these appear to contain a large quantity of vesicular parenchyma, in which the ramifications of the bronchial tubes subsequently extend themselves. About the tenth or eleventh day of incubation, these ramifications possess nearly their permanent character and situation. The first trace of the Glottis appears about the fifth day; it is then a mere slit in the walls of the œsophagus, resembling that by which the ductus pneumaticus of some Fishes opens into the alimentary canal. The formation of the cartilaginous rings of the trachea does not commence until after the twelfth day, when they first appear as transverse striæ on the median line of the front only; they gradually become solid, and extend themselves on either side, until at last they nearly meet on the median line, on the back or vertebral side of the tube.—The history of the process, in the Human embryo, appears to be very nearly the same. The first appearance of the Lungs takes place at about the 6th week, at which time they are simple elevations of the external layer of the œsophageal wall. Their surface, however, soon becomes studded with numerous little wart-like projections; and these are caused by the formation of corresponding enlargements of their cavity. These enlargements soon become prolonged, and develope corresponding bud-like enlargements from their sides; and in this manner, the form of the organs is gradually changed, a progressive increase in their bulk taking place from above downwards, in consequence of the extension of the bronchial ramifications from the single tube at the apex. At the same time, however, a corresponding increase in the amount of the parenchymatous tissue of the lung is taking place; for this is deposited in all the interstices between the bronchial ramifications, and might be compared with the soil filling up the spaces amongst the roots of a tree. It is in this parenchyma that the pulmonary vessels are distributed; and the

Fig. 176.


First appearance of the *Lungs*:—*a*, in a *Fowl* at four days; *b*, in a *Fowl* at six days; *c*, termination of bronchus in a very young *Pig*.

portion of it which extends beyond the terminations of the bronchial tubes, seems to act as the nidus for their further extension. It can be easily shown that, up to a late period of the development of the lungs, the dilated terminations of the bronchi constitute the only air-cells (Fig. 176, *c*); but, as already mentioned, the parenchyma subsequently has additional cavities formed within it.—It is a fact of some interest, as an example of the tendency of certain diseased conditions to produce a return to forms which are natural to the fœtal organism, or which present themselves in other animals, that up to a late period in the development of the Human embryo, the lungs do not nearly fill the cavity of the chest, and the pleura of each side contains a good deal of serous fluid.

1007. The embryological development of the *Urinary* organs in Vertebrated animals is a subject of peculiar interest; owing to the correspondence which may be traced between the transitory forms they present in the higher classes, and their permanent condition in the lower. In this respect, there is an evident analogy with the Respiratory system. The first appearance of anything resembling a Urinary apparatus in the Chick, is seen on the second half of the third day. The form at that time presented by it, is that of a long canal, extending on each side of the spinal column, from the region of the heart, towards the allantois (Fig. 174, *o, o*); on the sides of this are a series of elevations and depressions, indicative of the incipient development of cæca. On the 4th day, the *Corpora Wolffiana*, as they are then termed, are distinctly recognized as composed of a series of cæcal appendages which are attached along the whole course of the first-mentioned canal, opening into its outer side (Fig. 177 *a*). On the 5th day, these appendages are convoluted; and the body which they form acquires increased breadth and thickness. They evidently then possess a secreting function, and the fluid which they separate is poured by their long straight canals (*b, b*) into the cloaca. Between their component shut sacs, numbers of small points appear, which consist of little clusters of convoluted vessels, exactly analogous to the Corpora Malpighiana of the true kidney. These bodies remain as the permanent urinary organs of Fishes; but in the higher Vertebrata they give place to the true Kidneys, the development of which commences in the Chick about the 5th day. These are seen on the 6th day, as lobulated greyish masses (*c*), which seem to sprout from the outer edges of the Wolffian bodies, but which are really independent formations, springing from a mass of blastema behind them; and as they gradually increase in size and advance in development, the Wolffian bodies retrograde; so that at the end of fœtal life, the only vestige of them is to be found as a shrunk rudiment, situated (in the male) near the testes.—The history of the development of the Urinary organs in the Human embryo, seems to correspond closely with the foregoing. The Wolffian bodies begin to appear towards the end of the first month; and it is in the course of the 7th week, that the true Kidneys

FIG. 177.


State of the *Urinary* and *Genital Apparatus* in the early embryo of the Bird:—*a*, corpora Wolffiana; *b, b*, their excretory ducts; *c*, kidneys; *d*, ureter; *e, e*, testis.

first present themselves. From the beginning of the 3rd month, the diminution in the size of the Wolffian bodies goes on *pari passu* with the increase of the Kidneys; and at the time of birth, scarcely any traces of the former can be found. At the end of the 3rd month, the kidneys consist of seven or eight lobes, the future pyramids; their excretory ducts still terminate in the same canal, which receives those of the Wolffian bodies and of the sexual organs; and this opens, with the rectum, into a sort of cloaca, or sinus urogenitalis, analogous to that which is permanent in the oviparous Vertebrata. The Kidneys are at this time covered by the Supra-Renal capsules, which equal them in size; about the 6th month, however, these have decreased, whilst the kidneys have increased, so that their proportional weight is as 1 to $2\frac{1}{2}$. At birth, the weight of the Kidneys is about three times that of the Supra-Renal capsules, and they bear to the whole body the proportion of 1 to 80; in the adult, however, they are no more than 1 to 240. The Corpora Wolffiana are, when at their greatest development, the most vascular parts of the body next to the liver; four or five branches from the aorta are distributed to each, and two veins are returned from each to the vena cava. The upper veins and their corresponding arteries are converted into the Renal or emulgent vessels; and the lower into Spermatic vessels. The lobulated appearance of the kidney gradually disappears; partly in consequence of the condensation of the areolar tissue which connects its different portions, and partly through the development of additional tubuli in the interstices. The Urinary Bladder is formed quite independently of the secreting apparatus, being a part of the *allantois*, which itself serves as the receptacle for the urinary secretion formed by the Corpora Wolffiana. The part of the tube below this forms the Cloaca, or common termination of the intestinal and vesical apparatus. The sides of this cloaca, however, gradually approach one another, so as to form a transverse partition, which separates the Rectum from the Genito-urinary canal; and the urethra of the female is afterwards separated from the Vagina by a similar process.

1008. The essential parts of the *Generative Apparatus*, namely, the Testes in the male, and the Ovaria in the female, are first developed in immediate proximity with the Corpora Wolffiana (Fig. 177, *e*, *e*), and have been supposed to sprout forth from them; this, however, is not really the case, as they have an independent origin in a mass of blastema peculiar to themselves. They make their first appearance in the Chick about the fourth day, as delicate striæ on the Wolffian bodies; and at this period no difference can be detected between the Testes and the Ovaria, which originate in precisely the same manner. Like the kidneys, the germ-preparing organs increase in proportion with the diminution in the temporary structures; at first, their efferent ducts open into those of the Wolffian bodies, but they are subsequently separated by the formation of a partition, like that which separates the rectum from the cloaca. In the Human embryo, the rudiments of the sexual organs,—whether testes or ovaria,—first present themselves soon after the kidneys make their appearance, that is, towards the end of the 7th week. They are at first much prolonged, and seem to consist of a kind of soft, homogeneous blastema, in which the structure characteristic of each subsequently developes itself. The *Testis* gradually assumes its permanent form; the epididymis appears

in the tenth week; and the gubernaculum (a membranous process from the filamentous tissue of the scrotum, analogous to the round ligament arising from the labium and attached to the ovary of the female), which is originally attached to the vas deferens, gradually fixes itself to the lower end of the testis or epididymis. The Testes begin to descend at about the middle period of pregnancy; at the seventh month they reach the inner ring; in the eighth they enter the passage; and in the ninth they usually descend into the scrotum. The cause of this descent is not very clear: it can scarcely be due merely, as some have supposed, to the contraction of the gubernaculum; since that does not contain any fibrous structure, until after the lowering of the testes has commenced. It is well known that the testes are not always found in the scrotum at the time of birth, even at the full period. Upon an examination of 97 new-born infants, Wrisberg found both testes in the scrotum in 67, one or both in the canal in 17, in 8 one testis in the abdomen, and in 3 both testes within the cavity. Sometimes one or both testes remain in the abdomen during the whole of life; but this circumstance does not seem to impair their function. This condition is natural, indeed, in the ram.—The *Ovary* undergoes much less alteration, either in its intimate structure, or in its position. The efferent canal of the genital apparatus, which in the male forms a continuous connection with the tubular structure of the testes, remains detached from the ovary in the female, having a free terminal aperture, and thus constituting the Fallopian tube. These tubes are at first distinct on the two sides, but they gradually coalesce higher and higher up;* and it is by an increased development of this coalesced portion, that the Uterus is formed, the homologue of which in the male seems to be the (so-called) *Vesicula prostatica*, or 'sinus pocularis,' which is sometimes developed to a considerable size, and the relation of which to the orifices of the vasa deferentia is then seen to be essentially the same as that of the female uterus to the Fallopian tubes.†

1009. The history of the development of the External Organs of Generation in the two sexes, presents matter of great interest, from the light which is thrown by a knowledge of it upon the malformations of these organs, which are among the most common of all departures from the normal type of Human organization.— Not only is the distinction of sexes altogether wanting at first; but the conformation of the external parts of the apparatus is originally the same in Man and the higher Mammalia, as it permanently is in the Oviparous Vertebrata. For, about the 5th or 6th week of embryonic life, the opening of a *cloaca* may be seen externally, which receives the termination of the intestinal canal, the ureters, and the efferent ducts of the sexual organs; but at the 10th or 11th week, the anal aperture is separated from that of the genito-urinary canal or 'urogenital sinus,' by the development of a transverse band; and the urogenital sinus itself is gradually separated, by a process of division extending from before backwards or from above downwards, into a 'pars urinaria' and a 'pars genitalis,' the former of which, extend-

* For a sketch of those different conditions presented by the Uterus in the several orders of the Mammalian class, which depend upon the degree of this coalescence, see the Author's "Princ. of Phys., Gen. and Comp.," § 326 *aa.*

† See Prof. E. Weber's "Zusätze zur Lehre vom Baue und den Verrichtungen der Geschlechtsorgane," Leipzig, 1846.

ing towards the urachus, is converted into the urinary bladder. A partial representation of this phase of development, is found in the permanent condition of the Struthious Birds and of the Implacental Mammalia. The external opening of this canal is soon observed to be bounded by two folds of skin, the rudiments of the labia majora in the female, and of the two halves of the scrotum in the male; whilst between and in front of these, there is formed a penis-like body, surmounted by a gland, and cleft or furrowed along its under surface. This body in the female is retracted into the genito-urinary canal, and becomes the clitoris; whilst the margins of its furrow are converted into the nymphæ or labia minora. In the male, on the other hand, it increases in prominence, and becomes the penis; and the margins of the furrow at its under surface unite (at about the 14th week), and form a continuation of the now-contracted genito-urinary canal,—the previous orifice of which then closes-up. Now in a large proportion of cases of so-called *Hermaphrodism*, there has been either a want of completeness in the development of the male organs, so that they present a greater or less degree of resemblance to those of the female; or the developmental process has gone on to an abnormal extent in the female organs, so that they come to present a certain degree of resemblance to those of the male. One of the most common malformations of the *male* organs is 'hypospadias,' or an abnormal opening of the urethra at the base of the penis; this arises from incompleteness in the closure of the edges of its original furrow. But when the developmental process has been checked at an earlier period, the urogenital sinus may retain more nearly its original character, and may have a wide external opening beneath the root of the penis, so as to resemble the female vagina, whilst the penis is itself destitute of any trace of the urethral canal; in some of these cases, again, the testes have not descended into the scrotum; whilst the absence of beard, the shrillness of the voice, and the fulness of the mammæ, have contributed to impart a feminine character to these individuals, their male attributes, however, being determined by the *seminiferous* character of the essential organ, the testes.* In the *female* organs, on the other hand, a greater or less degree of resemblance to those of the male may be produced by the enlargement of the clitoris, by its furrowing or complete perforation by the urethra, by the closure of the entrance of the vagina and the cohesion of the labia, so as to present a likeness to the unfissured perineum and scrotum of the male, by the descent of the ovaries through the inguinal ring into the position of the male testes, by the imperfect development of the uterus and mammæ; and with these are usually associated roughness of the voice and growth of hair on the chin, and a psychical character more or less virile. *True* Hermaphrodism, in which there is an absolute combination of the essential male and female organs in the same individual, is comparatively rare. It may occur under the forms of *lateral* hermaphrodism, in which there is a genuine ovary on one side and a testis on the other, in which case the external organs are usually those of a hypospadic male; *transverse* hermaphrodism, in which the external and internal organs do not correspond, the former being male and the

* The *vesicula prostatica*, or 'uterus masculinus,' has presented an unusual development in some of these cases; see Prof. Weber (loc. cit.), and Prof. Theile's 'Account of a Case of Hypospadias,' in "Müller's Archiv.," 1847.

latter female, or *vice versâ*; — and *double* or *vertical* hermaphrodism, in which the proper organs characteristic of one sex have existed, with the addition of some of those of the other; this is the rarest of all, and it is not certain that the coexistence of testes and ovaria on the same side has ever been observed in the Human species.*

1010. We have now to follow the course of the development of the principal organs of *Animal* life; and shall first notice that of the *Skeleton.* —We have seen that, in the embryo of the Vertebrated animal, the future vertebral column is marked-out at an earlier period than any other permanent organ (§ 997); and that indications of a division into vertebræ are very speedily presented in the embryo of the higher classes. The earliest formation, however, is one of which we recognize no traces in the adult condition of Man; namely, a longitudinal column, tapering-off to a point at the cranial and caudal extremities of the embryo, and occupying the place of the future bodies of the vertebræ. This, which is termed the 'chorda dorsalis,' is of gelatinous consistence, and is composed entirely of cells; it is enclosed in a sheath, which gradually acquires the structure of a fibrous membrane, and which also invests the neural axis itself; and this condition is persistent in the Amphioxus and the Myxinoid Fishes,† which have never any other spinal column than the chorda dorsalis. The vertebræ seem to be developed, in the inferior Vertebrata, in the fibrous sheath of the chorda dorsalis; but in Birds and Mammals, the quadrangular plates which show themselves at a very early period (Plate II. Fig. 12), appear to have an independent origin. These gradually increase in number and size, so as to surround the chorda both above and below; sending out, at the same time, prolongations from the inferior surface, to form the arches destined to enclose the Spinal Cord or neural axis, which are hence termed by Prof. Owen the *neural arches.* In this primitive condition, the body and arches of each vertebra are formed by one piece on each side; and these, becoming cartilaginous, are united inferiorly by a suture, so as to enclose the chorda in a sort of case formed by the bodies of the vertebræ, which are still hollow, so as to allow the segments of the chorda partially separated from each other, to communicate together. This condition also remains persistent in certain of the Cartilaginous Fishes. With the concentric growth of the bodies of the vertebræ, however, the chorda dorsalis gradually wastes, and at last disappears; but previously to its disappearance, the ossification of the bodies and neural arches of the vertebræ begins, the former from a single point on the median line, the latter by separate points on the two sides.—The complete *typical vertebra* (Fig. 178, A) essentially consists, according to Prof. Owen,‡ of the *centrum,* around which are arranged four arches enclosed by processes in connection with it: viz., superiorly, the *neural* arch, which encloses the neural axis, and is formed by a pair of 'neurapophyses' (*n*, *n*) and a 'neural spine' (*n s*); inferiorly the *hæmal* arch, which is in like special relation with the centres of the circulation, but may be expanded around the visceral

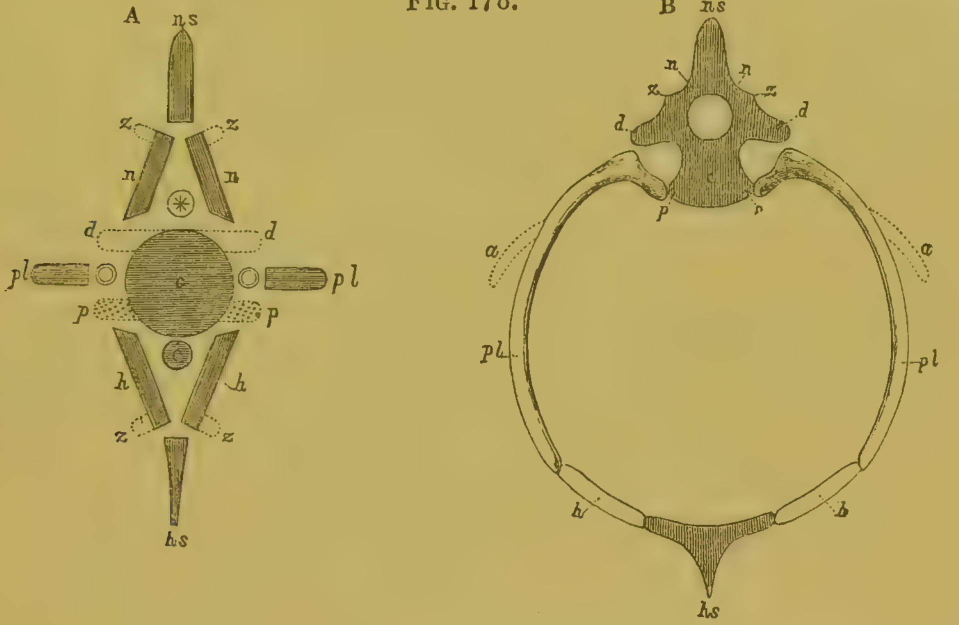
* On the subject of Hermaphrodism, see Prof. Simpson's Article in the "Cyclop. of Anat. and Phys.," vol. ii.

† "Princ. of Phys., Gen. and Comp.," §§ 321 *a*, 322, and 322 *a*.

‡ See his "Archetype Skeleton," his "Lectures on Comparative Anatomy," vol. ii., and his "Discourse on the Nature of Limbs."

cavity generally, and which is formed of a pair of 'hæmapophyses' (*h, h*) and the 'hæmal spine' (*h s*); and two *lateral* arches, enclosing vascular canals, which are bounded by the 'diapophyses' (*d, d*) and the 'parapophyses' (*p, p*), and are completed by the 'pleurapophyses' (*pl, pl*). Of these elements, the centrum is the most constant; and next to these are the neural arches, which we find in every part of the vertebral column

FIG. 178.




Elements of a *Vertebra*, according to Prof. Owen:—A, ideal typical vertebra:—B, actual thoracic vertebra of a Bird:—*c*, centrum, giving off *d, d*, the diapophyses, and *p, p*, the parapophyses; the neural arch, enclosing the spinal cord *, is formed by *n, n*, the neurapophyses and *n s*, the neural spine; the hæmal arch, enclosing the great centres of the circulation, is formed by *h, h*, the hæmapophyses, and *h s*, the hæmal spine. From both the neurapophyses and hæmapophyses may be given off the zygapophyses, *z, z*. The lateral arches, which may enclose the vertebral arteries o o, are completed by the pleurapophyses, *p l*; these in B are bent downwards, so as to form part of the hæmal arch, and give off the diverging appendages *a, a*.

through which the neural axis passes, and which are enormously developed in the cranial segments, in accordance with the high development of the nervous mass. The hæmal arches are often almost entirely deficient, as in the cervical and lumbar vertebræ of Man and the Mammalia: but in the dorsal vertebræ they are very largely developed, and the elements of the lateral arches are brought into connection with them, so as to form the enclosure of the visceral cavity (Fig. 178, B). From the pleurapophyses are occasionally developed a pair of 'diverging appendages' (*a, a*), which are well seen in the ribs of Birds; and these are considered by Prof. Owen to be the fundamental elements of the bones of the 'extremities' or 'limbs,' those of the anterior extremity being the diverging appendages of the occipital vertebra (§ 1011), and those of the posterior extremity standing in the same relation to one of the sacral vertebræ.*—The extremities themselves are developed, in all Vertebrata, as leaf-like elevations from the parietes of the trunk (Fig. 174, *q, q, r, r*); those peculiarities of form by which they are adapted to specialities of function, being determined by subsequent processes of development.

* The beautiful chain of reasoning by which this position is, in the Author's opinion, irrefutably established, is contained in the works of Prof. Owen already referred-to; a sketch of it, and of the whole 'Vertebral Theory,' will be found in the Author's "Princ. of Phys., Gen. and Comp.," § 320 *et seq.*

Thus in the Human fœtus, the fingers are at first united by the primitive blastema, as if webbed for swimming; but this, as Prof. Müller justly remarks, is less to be regarded as an approximation to the form of the extremity characteristic of aquatic animals, than as the primitive and most general form of the hand, the individual parts of which subsequently become more completely isolated in such animals as require to use them separately.

1011. It is in the *cranial* segments that the vertebral elements undergo their most remarkable transformations, the departure from the 'archetype' being more complete in Man than in any other animal; so that it is only by tracing them through their simplest to their most complicated forms and arrangements, that the true nature of the latter can be elucidated.*—The number of the segments entering into the skull has been a subject of much discussion among those who adopt the 'vertebral theory' of its composition; but Prof. Owen agrees with Oken (the original propounder of the theory) in fixing the number at *four*, which corresponds with that of the primary divisions, succeeding each other in a linear series, that are distinctly marked in the early development of the Encephalon, namely (proceeding from behind forwards), the Epencephalon, the Mesencephalon, the Prosencephalon, and the Rhinencephalon;† and also corresponding with the number of the nerves of special sense, the Auditory, Gustative, Optic, and Olfactory, which issue from this part of the neural axis with the same segmental regularity that the ordinary sensori-motor nerves do elsewhere.‡

* See especially Prof. Owen's "Archetype Skeleton," and the sketch contained in the Author's "Princ. of Phys., Gen. and Comp.," §§ 320 *i*, 320 *l*.

† The Rhinencephalon (consisting of the Olfactive ganglia) is seldom distinctly marked-out in the early stage of development of the higher Vertebrata, but is obvious enough in Fishes (Fig. 128, A).

‡ Under the guidance of the unerring light of Comparative Anatomy and Development, the composition of the Cranial portion of the skull—consisting of the *bodies* and *neural arches* of the four cranial vertebræ—has been determined by Prof. Owen as follows, each of the 'elements' enumerated being marked as distinct, by the separateness of its centre of ossification.

TABLE I.

*Composition of the Neural Arches of the Cranial Vertebræ, in Man.*

I. Epencephalic or Occipital Vertebra.

*Centrum;* Basi-occipital portion of the Occipital bone.

*Parapophyses; Neurapophyses;* Coalesced into the lateral or condyloid portions of the Occipital bone, the parapophyses being marked by the scabrous ridge giving attachment to the rectus lateralis muscle.

*Neural Spine;* Proper Occipital bone.

II. Mesencephalic or Parietal Vertebra.

*Centrum;* Basi-sphenoid, or body of the posterior or spheno-temporal part of the Sphenoid bone.

*Parapophyses;* Mastoid portion of the Temporal bones.

*Neurapophyses;* Great wings of Sphenoid bone, or Ali-sphenoids.

*Neural Spine;* Parietal bones.

III. Prosencephalic or Frontal Vertebra.

*Centrum;* Pre-sphenoid, or body of the anterior or spheno-orbital part of the Sphenoid bone.

*Parapophyses;* External angular processes of Frontal bone (the post-frontals of Fishes).

*Neurapophyses;* Small wings of Sphenoid bone, or Orbito-sphenoids.

*Neural Spine;* Frontal bone.

1012. Within the Cranio-spinal canal thus formed, the rudiment of he Cerebro-spinal axis is found, at first under a very different aspect rom that which it subsequently presents, especially as regards the relaive proportions of its different segments. The Encephalon, at about the 5th week, is seen as a series of vesicles arranged in a line with each other (Fig. 179); of which those that represent the Cerebrum (*b*) are the smallest, whilst that which represents the Cerebellum (*d*) is the largest. The latter (or *Epencephalon*), as in Fishes, is single, covering the fourth ventricle on the dorsal surface of the Medulla Oblongata. Anterior to this is the single vesicle (*a*) of the Corpora Quadrigemina (or *Mesencephalon*), from which the optic nerve chiefly arises; this has in its interior

IV. Rhinencephalic or Nasal Vertebra.
*Centrum;* Vomer.
*Neurapophyses;* Ossa plana of Ethmoid bone.
*Neural Spine;* Nasal bones.

In connection with the foregoing, we have two ossified 'sense-capsules;' the Auditory formed by the petrosal portion of the Temporal bone; and the Nasal formed by the principal part of the Ethmoid bone with the Turbinate bones.

The *hæmal arches* of the cranial vertebræ form the bones of the Face and of some other parts, as will be seen from the following table.

TABLE II.

*Composition of the Hæmal Arches of the Cranial Vertebræ, in Man.*

I. Epencephalic or Occipital Vertebra.
*Pleurapophyses;* Scapulæ.
*Diverging Appendages;* Bones of Arm, Fore-arm, and Hand.
*Hæmapophyses;* Coracoid processes of Scapulæ (Coracoid bones of Oviparous Vertebrata).
*Hæmal Spine;* Deficient.

[The Clavicles and first segment of the Sternum, which complete the Scapular arch in the Mammalia, are regarded by Prof. Owen as the hæmapophyses and hæmal spine of the atlas, or highest vertebra of the trunk.]

II. Mesencephalic or Parietal Vertebra.
*Pleurapophyses;* Styloid processes of Temporal bone.
*Diverging Appendages;* Greater cornua of Hyoid bone, or Thyro-hyals.
*Hæmapophyses;* Lesser cornua of Hyoid bone, or Cerato-hyals.
*Hæmal Spine;* Body of Hyoid bone.

III. Prosencephalic or Frontal Vertebra.
*Pleurapophyses;* Tympanic portion of Temporal bone.
*Diverging Appendages;* Deficient.
*Hæmapophyses;* Articular portion of Inferior Maxilla.
*Hæmal Spine;* Dental portion of inferior Maxilla.

IV. Rhinencephalic or Nasal Vertebra.
*Pleurapophyses;* Palatine bones.
*Diverging Appendages;* Pterygoid and Malar bones, with squamosal and zygomatic portions of Temporal bones.
*Hæmapophyses;* Superior Maxillary bones.
*Hæmal Spine;* Intermaxillary bones.

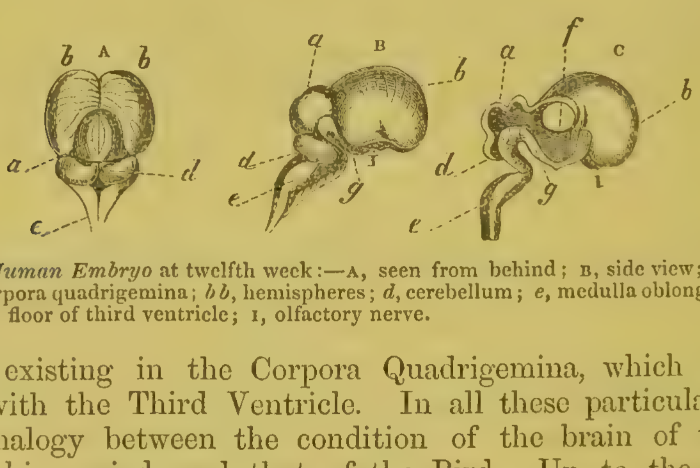
Thus we see that, in the anterior segment, we have the highest development of the visceral portion, co-existing with the lowest development of the neural; this last being obviously related to the comparatively low development of the ganglionic mass which it is destined to protect.—The development of the soft parts of the face takes place in conformity with that of the vertebral segments; these being formed by 'visceral arches' which meet on the median line (Fig. 174, *c*, *d d*); and the knowledge of this fact enables us to explain those congenital malformations which result from want of union of the two halves on the median plane, such as cleft palate and hare-lip.

a cavity, the ventricle of Sylvius, which is persistent in the adult Bird, though obliterated in the adult Mammal. In front of this is the vesicle (*c*) of the Third Ventricle (or *Deutencephalon*), which contains also the Thalami Optici; as development proceeds, this, like the preceding, is covered by the enlarged hemispheres; whilst its roof becomes cleft anteriorly on the median line, so as to communicate with the cavities which they include. Still more anteriorly (*b*) is the double vesicle (or *Prosencephalon*) which represents the hemispheres of the Cerebrum; this has a cavity on either side, the floor of which is formed by the Corpora Striata, and which has at first no opening except into the third ventricle; the 'fissure of Sylvius' (which enables the membranes of the brain to be reflected into the lateral ventricles) being formed at a later period. In the small proportion which the Cerebral Hemispheres bear to the other parts, the absence of convolutions, the deficiency of commissures, and the general simplicity of structure of the whole, there is a certain correspondence between the brain of the Human embryo at this period, and that of a Fish; but the resemblance is much stronger between the *fœtal* brain of the Fish and that of the Mammal; indeed at this early period of their formation, the two could scarcely be distinguished; and it is the large amount of change which the latter undergoes, as compared with the former, that causes the wide dissimilarity of their adult forms. — At about the 12th week we find the Cerebral Hemispheres much increased in size, and arching-back over the Thalami and Corpora Quadrigemina (Fig. 180); still, however, they are destitute of convolutions, and imperfectly connected by commissures; and there is a large

Fig. 179.


*Human Embryo* of sixth week, enlarged about three times: — *a*, vesicle of Corpora Quadrigemina; *b*, vesicle of Cerebral Hemispheres; *c*, vesicle of Third Ventricle; *d*, vesicle for Cerebellum and Medulla Oblongata; *e*, auditory vesicle; *f*, olfactory fossa; *h*, liver; * * caudal extremity.

Fig. 180.




Brain of *Human Embryo* at twelfth week:—A, seen from behind; B, side view; C, sectional view;—*a*, corpora quadrigemina; *b b*, hemispheres; *d*, cerebellum; *e*, medulla oblongata; *f*, optic thalamus; *g*, floor of third ventricle; I, olfactory nerve.

cavity still existing in the Corpora Quadrigemina, which freely communicates with the Third Ventricle. In all these particulars, there is a strong analogy between the condition of the brain of the Human embryo at this period, and that of the Bird.—Up to the end of the 3rd month, the Cerebral Hemispheres present only the rudiments of

*anterior* lobes, and do not pass beyond that grade of development which is permanently characteristic of the Marsupial Mammalia, the Thalami being still but incompletely covered-in by them. During the 4th and part of the 5th months, however, the middle lobes are developed from their posterior aspect, and cover the Corpora Quadrigemina; and the posterior lobes, of which there was no previous rudiment, subsequently begin to sprout from the back of the middle lobes, remaining separated from them, however, by a distinct furrow, even in the brain of the mature fœtus, and sometimes in that of older persons. In these and other particulars, there is a very close correspondence between the progressive stages of development of the Human Cerebrum, and those which we encounter in the ascending scale of Mammalia.*

1013. The development of the two principal Organs of Sense, the Eye and the Ear, has been made the subject of careful study (in the Chick) by Mr. H. Gray.†—The development of the Eye commences by a protrusion from the posterior part of the anterior cerebral vesicle, representing the 'vesicle of the thalami optici,' which is at that time hollow; and the cavity of the protrusion is continuous with that of the vesicle itself, which remains as the 'third ventricle.' This protrusion is lined, like the cerebral vesicle, with granular matter, which gradually becomes distinctly cellular, forming a layer of a truly ganglionic character; and whilst this change is taking place, the protrusion increases, becomes pear-shaped, and is at last connected only by a narrow pedicle with the vesicle from which it sprang. This pedicle closes up, so as completely to separate the two cavities; and the one which has been thus budded-forth constitutes the rudiment of the eye, whilst the other goes-on to form the ganglionic bodies at the base of the cerebrum, the connecting pedicle becoming the optic nerve, which connects the retina with its ganglionic centre. The spherical extremity of the protrusion is absorbed, and the retina, or vesicular lining, becomes attached to the margin of the lens, which is in the mean time developed in the interior of the cavity, and is at first completely surrounded by the retina. The formation of the coats of the Eye takes place subsequently; the development even of the 'fibrous lamina' and of the 'membrana Jacobi' of the retina itself, not taking place until after its cellular layer has been very distinctly formed. It is a curious circumstance, and one not very easy to account for, that the development of the Eye should take place from the Deutencephalic and not from the Mesencephalic vesicle; as it is in the latter that the proper 'optic ganglia' originate, with which the optic nerves come at last to have their principal connection, their connection with the 'thalami optici' being much less close. — The Auditory apparatus takes its origin in a portion of the Epencephalic vesicle, which protrudes on either side, its cavity at first communicating with that of the vesicle, which remains permanent as the 'fourth ventricle.' As its protrusion increases, it becomes elongated and pear-shaped, and is only connected with the central mass by a pedicle whose canal gradually closes-up; the sac thus cut off becomes the vestibular cavity, and the pedicle the auditory nerve. At first there is no vestige either of cochlea, semicircular

* See an account of the observations of Prof. Retzius on the Development of the Cerebrum, in the "Archives d'Anatomie Générale et de Physiologie," 1846.

† "Philosophical Transactions," 1850.

canals, or tympanic apparatus; but the sac presents the simple character which it permanently retains in the Cephalopoda and the lower Fishes. Gradually, however, the semicircular canals are developed, by a contraction and folding-in of the walls of the vestibular sac; and the cochlea is probably formed as an offset from it. At the same time, the formation of cartilage, and subsequently of bone, takes place around the auditory sac and its prolongations, forming the 'sense-capsule,' which, in the higher Vertebrata, coalesces with the vertebral elements to form the temporal bone.—It is very interesting to remark, that the membranous labyrinth, between the eighth and thirteenth days in the Chick, has a structure almost precisely similar to that of the retinal expansion of the same period; consisting, like it, of a distinct but very delicate fibrous mesh, in the spaces between which are deposited a quantity of granular matter and numerous nucleated cells, whilst its exterior is composed of a dense mass of nuclei, almost precisely analogous to the granular particles which form a large part of the entire substance of the retina.

1014. There can be no reasonable doubt, that the developmental process must be greatly influenced by the *quality* of the nutriment supplied by the maternal blood. "We have demonstrative evidence," says Dr. A. Combe,* "that a fit of passion in a nurse vitiates the quality of the milk to such a degree, as to cause cholic and indigestion (or even death) in the suckling infant. If, in the child already born, and in so far independent of its parent, the relation between the two is thus strong, is it unreasonable to suppose that it should be yet stronger, when the infant lies in its mother's womb, is nourished indirectly by its mother's blood, and is, to all intents and purposes, a part of her own body? If a sudden and powerful emotion of her own mind exerts such an influence upon her stomach as to excite immediate vomiting, and upon her heart as almost to arrest its motion and induce fainting, can we believe that it will have no effect on her womb and the fragile being contained within it? Facts and reason, then, alike demonstrate the reality of the influence: and much practical advantage would result to both parent and child, were the conditions and extent of its operations better understood." Among facts of this class, there is, perhaps, none more striking than that quoted by the same author from Baron Percy, as having occurred after the siege of Landau in 1793. In addition to a violent cannonading, which kept the women for some time in a constant state of alarm, the arsenal blew up with a terrific explosion, which few could hear with unshaken nerves. Out of 92 children born in that district within a few months afterwards, Baron Percy states that 16 died at the instant of birth; 33 languished for from 8 to 10 months, and then died; 8 became idiotic, and died before the age of 5 years; and 2 came into the world with numerous fractures of the bones of the limbs, caused by the cannonading and explosion. Here, then, is a total of 59 children out of 92, or within a trifle of 2 out of every 3, actually killed through the medium of the Mother's alarm and the natural consequences upon her own organization; an experiment (for such it is to the Physiologist) upon too large a scale for its results to be set down as mere 'coincidences.'—No soundly-judging Physiologist of the present day is likely to fall into the popular

* "On the Management of Infancy," p. 76.

or, of supposing that 'marks' upon the Infant are to be referred to ne *transient* though strong impression upon the imagination of the ther.; but there appear to be a sufficient number of facts on record, to ve that *habitual* mental conditions on the part of the Mother *may* e influence enough, at an early period of gestation, to produce evident lily deformity, or peculiar tendencies of the mind. That the mental te of the Mother can produce important alterations in her own blood, ms demonstrated by the considerations previously adduced (CHAP. II.) in regard to its effect upon the processes of Nutrition and Secre- 1; and that such alterations are sufficient to determine important difications in the developmental processes of the Embryo, to which blood furnishes the materials, can scarcely admit of a question, when recollect what an influence the presence or absence of particular stances has in modifying the growth of parts in the adult (§ 203). e error of the vulgar notion on this subject, lies in supposing that *a lden fright, speedily forgotten,* can exert such a continual influence on nutrition of the Embryo, as to occasion any personal peculiarity.* e view here stated is one which ought to have great weight, in making nifest the importance of careful management of the health of the ther, both corporeal and mental, during the period of pregnancy; ce the constitution of the offspring so much depends upon the impres- ns then made upon its most impressible structure.

1015. It is frequently of great importance, both to the Practitioner l to the Medical Jurist, to be able to determine the *age* of a Fœtus, m the physical characters which it presents; and the following table been framed by Devergie† in order to facilitate such determination. is to be remarked, however, that the *absolute length* and *weight* of Embryo are much less safe criteria, than its *degree of development,* indicated by the relative evolution of the several parts which make ir appearance successively. Thus it is very possible for one child, n at the full time, to weigh less than another, born at 8 or even at 7 nths; its length, too, may be no greater: but the position of the ddle point of the body will usually afford sufficient ground for the ermination; since, during the two latter months of pregnancy, the in- asing development of the lower extremities brings it lower down.

*mbryo* 3 *to* 4 *weeks.*—It has the form of a serpent; — its length from 3 to 5 lines; head indicated by a swelling;—its caudal extremity (in which is seen a white line, indi- ng the continuation of the medulla spinalis), slender, and terminating in the umbilical l;—the mouth indicated by a cleft, the eyes by two black points; the members begin ppear as nipple-like protuberances;—the liver occupies the whole abdomen;—the bladder ery large. The chorion is villous, but its villosities are still diffused over the whole ace.

*mbryo of* 6 *weeks.*—Its length from 7 to 10 lines;—its weight from 40 to 75 grains;— distinct from cranium;—aperture of nose, mouth, eyes, and ears perceptible;—head

---

* For some valuable observations on this subject, see Montgomery "On the Signs of gnancy."—Numerous cases have been recorded, during the last few years (especially in "Lancet" and "Provincial Medical Journal"), in which malformations in the Infant eared distinctly traceable to strong impressions made on the mind of the Mother some ths previously to parturition; these impressions having been persistent during the aining period of pregnancy, and giving rise to a full expectation on the part of the ther, that the child would be affected in the particular manner which actually occurred.

† "Médecine Légale," 3ième edit. tom. i. p. 279.

distinct from thorax;—hands and fore-arms in the middle of the length, fingers distinct;—legs and feet situated near the anus;—clavicle and maxillary bone present a point of ossification; — distinct umbilicus for attachment of cord, which at that time consists of the omphalo-meseraic vessels, of a portion of the urachus, of a part of the intestinal tube, and of filaments which represent the umbilical vessels. The placenta begins to be formed;—the chorion still separated from the amnion;—the umbilical vesicle very large.

*Embryo of* 2 *months.*—Length from 16 to 19 lines;—weight from 150 to 300 grains;—elbows and arms detached from the trunk;—heels and knees also isolated;—rudiments of the nose and of the lips;—palpebral circle beginning to show itself;—clitoris or penis apparent;—anus marked by a dark spot;—rudiments of lungs, spleen, and supra-renal capsules;—cæcum placed behind the umbilicus;—digestive canal withdrawn into the abdomen;—urachus visible;—osseous points in the frontal bone and in the ribs.—Chorion commencing to touch the amnion at the point opposite the insertion of the placenta; placenta begins to assume its regular form;—umbilical vessels commence twisting.

*Embryo of* 3 *months.*—Length from 2 to $2\frac{1}{2}$ inches;—weight from 1 oz. to $1\frac{1}{2}$ oz. (Troy);—head voluminous;—eyelids in contact by their free margin; membrana pupillaris visible;—mouth closed;—fingers completely separated;—inferior extremities of greater length than rudimentary tail;—clitoris and penis very long;—thymus as well as supra-renal capsules present;—cæcum placed below the umbilicus;—cerebrum 5 lines, cerebellum 4 lines, medulla oblongata $1\frac{1}{2}$ line, and medulla spinalis $\frac{3}{4}$ of a line, in diameter;—two ventricles of heart distinct.—The decidua reflexa and decidua uterina in contact;—funis contains umbilical vessels and a little of the gelatine of Warthon;—placenta completely isolated;—umbilical vesicle, allantois, and omphalo-meseraic vessels have disappeared.

*Fœtus of* 4 *months.*—Length 5 to 6 inches;—weight $2\frac{1}{2}$ to 3 oz.;—skin rosy, tolerably dense;—mouth very large and open;—membrana pupillaris very evident;—nails begin to appear;—genital organs and sex distinct;—cæcum placed near the right kidney;—gall-bladder appearing;—meconium in duodenum;—cæcal valve visible;—umbilicus placed near pubis;—ossicula auditoria ossified;—points of ossification in superior part of sacrum;—membrane forming at point of insertion of placenta on uterus;—complete contact of chorion with amnion.

*Fœtus of* 5 *months.*—Length 6 to 7 inches;—weight 5 to 7 oz.;—volume of head still comparatively great;—nails very distinct;—hair beginning to appear;—skin without sebaceous covering;—white substance in cerebellum;—heart and kidneys very voluminous;—cæcum situated at inferior part of right kidney;—gall-bladder distinct;—germs of permanent teeth appear;—points of ossification in pubis and calcaneum;—meconium has a yellowish-green tint, and occupies commencement of large intestine.

*Fœtus of* 6 *months.*—Length 9 to 10 inches;—weight 1 lb.;—skin presents some appearance of fibrous structure;—eyelids still agglutinated, and membrana pupillaris remains;—sacculi begin to appear in colon;—funis inserted a little above pubis;—face of a purplish red;—hair white or silvery;—sebaceous covering begins to present itself;—meconium in large intestine;—liver of dark red;—gall-bladder contains serous fluid destitute of bitterness;—testes near kidneys;—points of ossification in four divisions of sternum;—middle point at lower end of sternum.

*Fœtus of* 7 *months.*—Length 13 to 15 inches;—weight 3 to 4 lbs.;—skin of rosy hue, thick, and fibrous;—sebaceous covering begins to appear;—nails do not yet reach extremities of fingers;—eyelids no longer adherent;—membrana pupillaris disappearing;—a point of ossification in the astragalus;—meconium occupies nearly the whole of large intestine;—valvulæ conniventes begin to appear;—cæcum placed in right iliac fossa;—left lobe of liver almost as large as right;—gall-bladder contains bile;—brain possesses more consistency;—testicles more distant from kidneys;—middle point at a little below end of sternum.

*Fœtus of* 8 *months.*—Length 14 to 16 inches;—weight 4 or 5 lbs.;—skin covered with well-marked sebaceous envelope;—nails reach extremities of fingers;—membrana pupillaris becomes invisible during this month;—a point of ossification in last vertebra of sacrum;—cartilage of inferior extremity of femur presents no centre of ossification;—brain has some indications of convolutions;—testicles descend into internal ring;—middle point nearer the umbilicus than the sternum.

*Fœtus of* 9 *months, the full term.*—Length from 17 to 21 inches;—weight from 5 to 9 lbs., the average probably about $6\frac{1}{2}$ lbs.;—head covered with hair in greater or less quantity, of from 9 to 12 lines in length;—skin covered with sebaceous matter, especially at bends of joints;—membrana pupillaris no longer exists;—external auditory meatus still cartilaginous;—four portions of occipital bone remain distinct;—os hyoides not yet ossified;—point of ossification in the centre of cartilage at lower extremity of femur;—white and grey substances of brain become distinct;—liver descends to umbilicus;—testes have passed inguinal ring, and

frequently found in the scrotum;—meconium at termination of large intestine;—middle
...nt of body at umbilicus, or a little below it.

1016. Even at birth, there is a manifest difference in the physical con...ions of infants of different sexes; for, in the average of a large number, ...ere is a decided preponderance on the side of the Males, both as to the ...ngth and the weight of the body.

...a. The length of the body in fifty new-born infants of each sex, as ascertained by Quete-... * was as follows:—

| | Males. | Females. | Total. |
|---|---|---|---|
| From 16 to 17 inches† (French) . . | 2 | 4 | 6 |
| „ 17 to 18 . . . . . . | 8 | 19 | 27 |
| „ 18 to 19 . . . . . . . | 28 | 18 | 46 |
| „ 19 to 20 . . . . . . | 12 | 8 | 20 |
| „ 20 to 21 . . . . . . . | 0 | 1 | 1 |

...om these observations, the mean and the extremes of the Lengths of the Male and ...male respectively, were calculated to be,—

| | Males. | | Females. | |
|---|---|---|---|---|
| Minimum . . | 16 inches, | 2 lines | 16 inches, | 2 lines |
| Mean . . . | 18 | 6 | 18 | $1\frac{1}{2}$ |
| Maximum . . | 19 | 8 | 20 | 6 |

...twithstanding that the *maximum* is here on the side of the Female (this being an acci-...tal result, which would probably have been otherwise, had a larger number been exa-...ned), the *average* shows a difference of $4\frac{1}{2}$ lines in favour of the Male.

... The inequality in the Weight of the two is even more remarkable; the observations of ... Quetelet ‡ were made upon 63 male and 56 female infants.

| Infants weighing from | Males. | Females. | Total. |
|---|---|---|---|
| 1 to $1\frac{1}{2}$ kilog. § . . . . . | 0 | 1 | 1 |
| $1\frac{1}{2}$ to 2 . . . . . . | 0 | 1 | 1 |
| 2 to $2\frac{1}{2}$ . . . . . . . | 3 | 7 | 10 |
| $2\frac{1}{2}$ to 8 . . . . . . | 13 | 14 | 27 |
| 3 to $3\frac{1}{2}$ . . . . . . . | 28 | 23 | 51 |
| $3\frac{1}{2}$ to 4 . . . . . . | 14 | 7 | 21 |
| 4 to $4\frac{1}{2}$ . . . . . . . | 5 | 3 | 8 |

...e extremes and means were as follows:—

| | Males. | Females. |
|---|---|---|
| Minimum . . . | 2·34 kilog. | 1·12 |
| Mean . . . | 3·20 | 2·91 |
| Maximum . . . | 4·50 | 4·25 |

... The average weight of infants of both sexes, as determined by these inquiries, is 3·05 ...og. or 6·7 lbs.; and this corresponds almost exactly with the statement of Chaussier, ...ose observations were made upon more than 20,000 infants. The mean obtained by him, ...hout reference to distinction of sex, was 6·75 lbs.; the maximum being 11·3 lbs., and minimum 3·2 lbs.‖ The average in this country is probably rather higher; according to Joseph Clarke,¶ whose inquiries were made on 60 males and 60 females, the average of ...le children is $7\frac{1}{2}$ lbs.: and that of Females $6\frac{5}{8}$ lbs. He adds that children which at the time weigh less than 5 lbs. rarely thrive; being generally feeble in their actions, and ...ng within a short time. Several instances are on record, of infants whose weight at ...h exceeded 15 lbs. It appears that healthy females, living in the country, and engaged ...active but not over-fatiguing occupations, have generally the largest children; and this is ...at might be expected *à priori*, from the superior energy of their nutritive functions.

* "Sur L'Homme," tom. ii. p. 8.
† The French inch is about one-fifteenth more than the English.
‡ Op. Cit. tom. ii. p. 35.
§ The kilogramme is equal to $2\frac{1}{5}$ lbs. avoirdupois.
‖ These numbers have been erroneously stated in many Physiological works; owing to ... difference between the French and English pound not having been allowed for.
¶ "Philosophical Transactions," vol. lxxvi.

1017. Notwithstanding that, in any ordinary population, there is a decided preponderance in the number of Females, the number of Male *births* is considerably greater than that of females. Taking the average of the whole of Europe, the proportion is about 106 Males to 100 Females. It is curious, however, that this proportion is considerably different for legitimate and for illegitimate births; the average of the latter being only $102\frac{1}{2}$ to 100, in the places where that of the former was $105\frac{3}{4}$ to 100. This is probably to be accounted for by the fact, which is one of the most remarkable contributions that have yet been made by Statistics to Physiology, that the Sex of the offspring is influenced by the relative *ages* of the parents. The following table expresses the average results obtained by M. Hofacker* in Germany, and by Mr. Sadler† in Britain; between which it will be seen that there is a manifest correspondence, although both were drawn from a too limited series of observations. The numbers indicate the proportion of Male births to 100 Females, under the several conditions mentioned in the first column.

| | Hofacker. | | Sadler. |
|---|---|---|---|
| Father younger than Mother | 90·6 | Father younger than Mother | 86·5 |
| Father and Mother of equal age | 90·0 | Father and Mother of equal age | 94·8 |
| Father older by 1 to 6 years | 103·4 | Father older by 1 to 6 years | 103·7 |
| „ „ 6 to 9 | 124·7 | „ „ 6 to 11 | 126·7 |
| „ „ 9 to 18 | 143·7 | „ „ 11 to 16 | 147·7 |
| „ „ 18 and more | 200·0 | „ „ 16 and more | 163·2 |

From this it appears, that the more advanced age of the Male parent has a very decided influence in occasioning a preponderance in the number of Male infants; and, as the state of society generally involves a condition of this kind in regard to marriages, whilst in the case of illegitimate children the same does not hold good, the difference in the proportional number of male births is accounted-for. We are not likely to obtain data equally satisfactory in regard to the influence of more advanced age on the part of the Female parent; as a difference of 10 or 15 years on that side is not so common. If it exist to the same extent, it is probable that the same law would be found to prevail in regard to Female children born under such circumstances, as has been stated with respect to the Male;—namely, that the mortality is greater during embryonic life and early infancy, so that the preponderance is reduced.

1018. There appears to be, from the first, a difference in the *Viability* (or probability of life) of Male and Female children; for, out of the total number born dead, there are 3 Males to 2 Females: this proportion gradually lessens, however, during early infancy; being about 4 to 3 during the first two months, and about 4 to 5 during the next three months; after which time the deaths are nearly in proportion to the numbers of the two sexes respectively, until the age of puberty. The viability of the two sexes continues to increase during childhood; and attains its maximum between the 13th and 14th years. For a short time after this epoch has been passed, the rate of mortality is higher in Females than in Males; but from about the age of 18 to 28, the mortality is much greater in Males, being at its maximum at 25, when the

* "Annales d'Hygiène," Oct. 1829. † "Law of Population," vol. ii. p. 343.

ıbility is only half what it is at puberty. This fact is a very striking ıe; and shows most forcibly that the indulgence of the passions not ly weakens the health, but in a great number of instances is the cause a very premature death. From the age of 28 to that of 50, the ortality is greater and the viability less on the side of the Female; ıis is what would be anticipated from the increased risk to which she is ıble during the parturient period. After the age of 50, the mortality nearly the same for both.

a. These facts have been expressed by Quetelet (Op. cit.) in a form which brings them ›minently before the eye (Fig. 181). The relative viability of the Male at different ages represented by a curved line; the elevation of which indicates its degree, at the respective riods marked along the base line. The dotted line which follows a different curve, repre- ıts the viability of the Female. Starting from *a*, the period of birth, we arrive at the

Fig. 181.

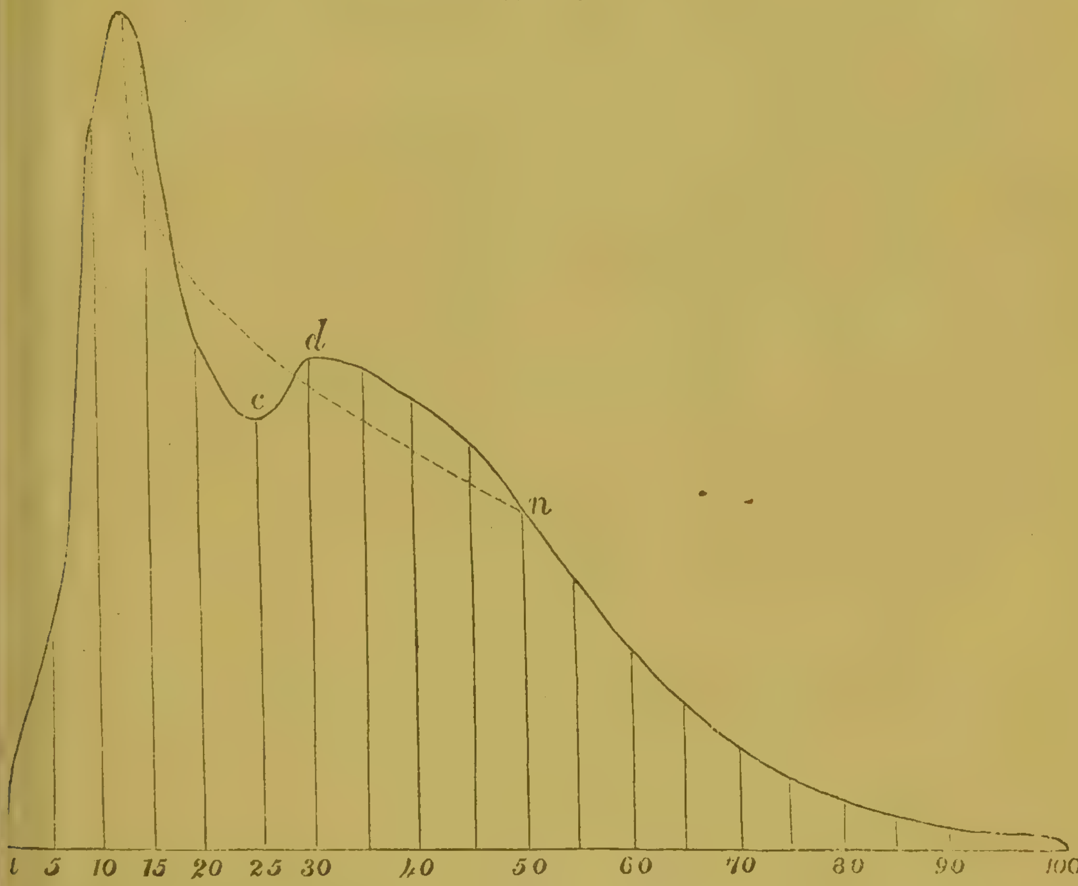



Diagram representing the *Comparative Viability of the Male and Female* at different Ages.

ıximum of viability for both at *b*; from this point, the Female curve steadily descends wards *n*, at first very rapidly, but afterwards more gradually; whilst the Male curve does t quite descend so soon, but afterwards falls much lower, its minimum being *c*, which rresponds with the age of 25 years. It afterwards ascends to *d*, which is the maximum of ıbility subsequently to the age of puberty; this point is attained at the age of 30 years, ›m which period, up to 50, the probability of life is greater in the Male than in the Female. ı the decline of life there seems little difference for the two sexes.

1019. Similar diagrams have been constructed by Quetelet, to indicate ıe relative *Heights* and *Weights* of the two sexes at different ages Fig. 182).

*a*. In regard to Height it may be observed, that the increase is most rapid in the first year, d that it afterwards diminishes gradually; between the ages of 5 and 16 years, the annual

increase is very regular. The difference between the Height of the Male and Female, which has been already stated to present itself at birth, continues to increase during infancy and youth; it is not very decided, however, until about the 15th year, after which the growth of the Female proceeds at a much diminished rate, whilst that of the Male continues in nearly the same degree, until about the age of 19 years. It appears, then, that the Female comes to her full development in regard to Height, earlier than does the Male. It seems probable, from the observations of Quetelet, that the full Height of the Male is not generally attained until the age of 25 years. At about the age of 50, both Male and Female undergo a diminution of their stature, which continues during the latter part of life.

Fig. 182.

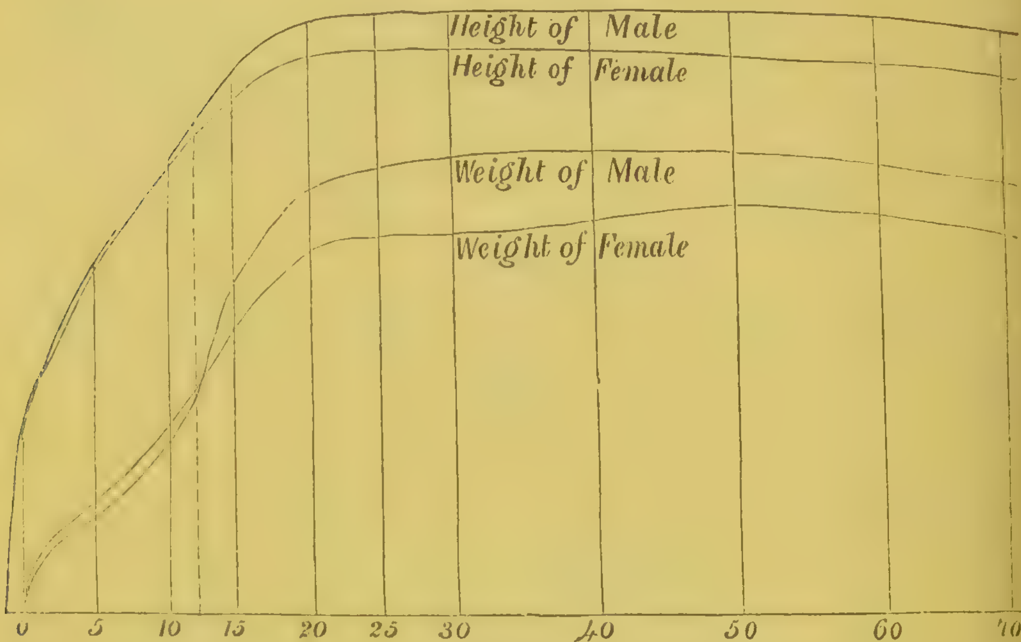



Diagram representing the *Comparative Heights and Weights* of the Male and Female at different ages.

*b.* The proportional Weight of the two sexes at different periods, corresponds pretty closely with their height. Starting from birth, the predominance then exhibited by the Male gradually increases during the first few years; but towards the period of puberty, the proportional weight of the Female increases; and at the age of 12 years, there is no difference between the two sexes in this respect. The weight of the Male, however, then increases much more rapidly than that of the Female, especially between the ages of 15 and 20 years; after the latter period, there is no considerable increase on the side of the Male, though his maximum is not attained until the age of 40; and there is an absolute diminution on the part of the Female, whose weight remains less during nearly the whole period of child-bearing. After the termination of the parturient period, the weight of the Female again undergoes an increase, and its maximum is attained about 50. In old age, the weight of both sexes undergoes a diminution in nearly the same degree. The average Weights of the Male and Female, that have attained their full development, are twenty times those of the new-born Infants of the two sexes respectively. The Heights, on the other hand, are about 3¼ times as great.

1020. The chief differences in the *Constitution* of the two sexes, manifest themselves during the period when the Generative function of each is in the greatest vigour. Many of these distinctions have been already alluded-to; but there are others of too great importance to be overlooked; and these chiefly relate to the Nervous System and its functions. There is no obvious structural difference in the Nervous System of the two sexes (putting aside the local peculiarities of its distribution to the organs

generation), save the inferior size of the Cerebral Hemispheres in the emale. This difference, which is not observed in other parts of the Encealon, is readily accounted-for on the principles formerly stated (§§ 782, 33), when we compare the psychical character of Woman with that of an; for there can be no doubt that—putting aside the exceptional cases hich now and then occur—the *intellectual* powers of Woman are inferior those of Man. Although her perceptive faculties are more acute, her pability of sustained mental exertion is much less; and though her views e often peculiarly distinguished by clearness and decision, they are genelly deficient in that comprehensiveness which is necessary for their ability. With less of the *volitional* powers than Man possesses, she has the *otional* and *instinctive* in a much stronger degree. The emotions, therere predominate; and more frequently become the leading springs of action, an they are in Man. By their direct influence upon the bodily frame, ey produce changes in the organic functions, which far surpass in degree ything of the same kind that we ordinarily witness in Man; and they us not unfrequently occasion symptoms of an anomalous kind, which e very perplexing to the Medical practitioner, though very interesting to e Physiological observer. But they also act as powerful motives to the ill; and, when strongly called forth, produce a degree of vigour and demination, which is very surprising to those who have usually seen the dividual under a different aspect. But this vigour, being due to the ong excitement of the Feelings, and not to any inherent strength of tellect, is only sustained during the persistence of the motive, and fails soon as this subsides. The feelings of Woman, being frequently called th by the occurrences she witnesses around her, are naturally more sinterested than those of Man; *his* energy is more concentrated upon e object; and to this his intellect is directed with an earnestness that frequently either blunts his feelings, or carries them along in the me channel, thus rendering them selfish. The *intuitive* powers of oman are certainly greater than those of Man. Her perceptions are ore acute, her apprehension quicker; and she has a remarkable power interpreting the feelings of others, which gives to her, not only a much ore ready sympathy with these, but that power of guiding her actions as to be in accordance with them, which we call *tact*. This tact bears close correspondence with the *adaptiveness* to particular ends, which we in Instinctive actions.—In regard to the inferior development of her tellectual powers, therefore, and in the predominance of the Instinctive, oman must be considered as ranking below Man; but in the superior rity and elevation of her Feelings, she is as highly raised above him. r whole character, Psychical as well as Corporeal, is beautifully apted to supply what is deficient in Man; and to elevate and refine ose powers, which might otherwise be directed to low and selfish jects.

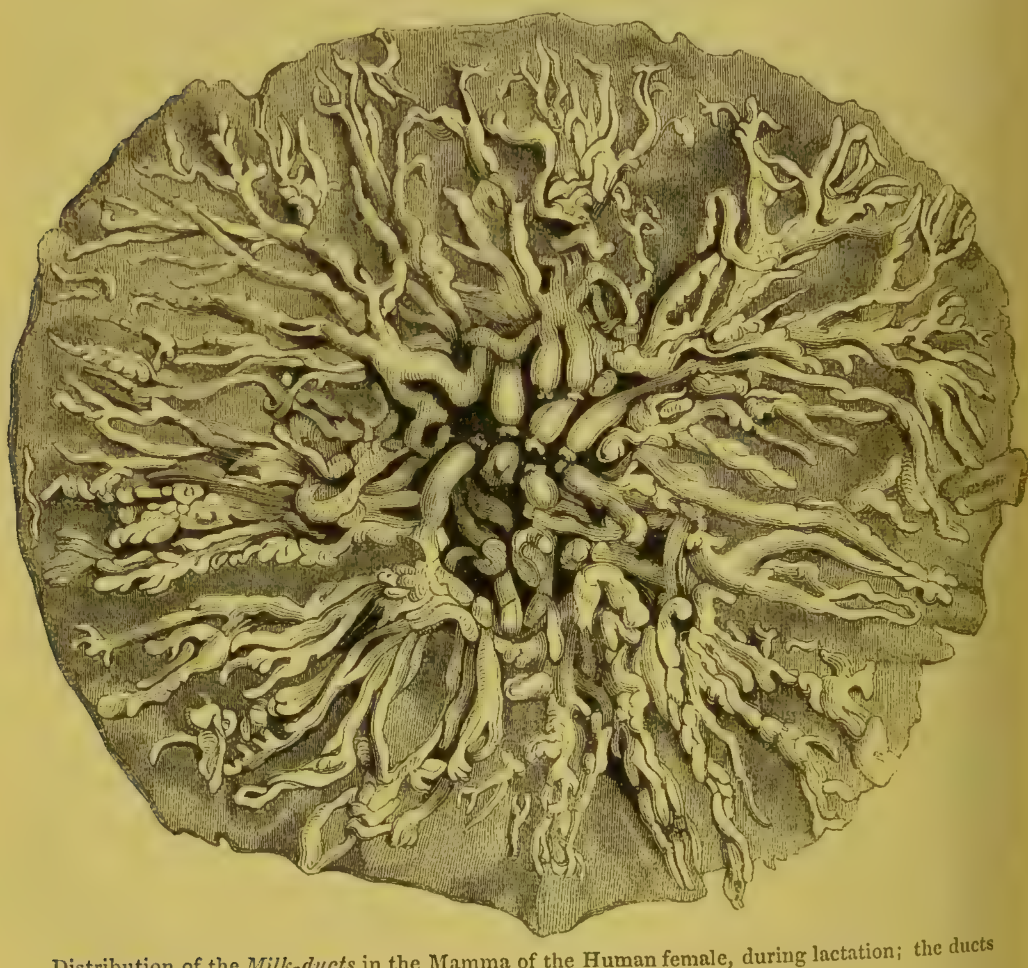
## 5.—*Of Lactation*,

1021. The new-born Infant in the Human species, as in the class of ammalia generally, is supplied with nourishment by a secretion elaboed from the blood of its maternal parent, by certain glandular organs own as the *Mammary*. The structure of these, which has been

3 Y

thoroughly investigated by Sir A. Cooper* and Mr. Birkett,† is extremely simple. Each gland is composed of a number of separate glandules, which are connected together by fibrous or fascial tissue, in such a manner as to allow a certain degree of mobility of its parts, one upon another, which may accommodate them to the actions of the pectoralis muscle whereon they are bound down; and the glandules are also connected by the ramifications of the lactiferous tubes, which intermingle with one another in such a manner as to destroy the simplicity and uniformity of their divisions, although they rarely inosculate. The *mammillary tubes*, or terminal ducts contained in the nipple, are usually about ten or twelve in number; they are straight, but of somewhat variable size; and their orifices, which are situated in the centre of the nipple, and are usually concealed by the overlapping of its sides, are narrower than the tubes themselves. At the base of the nipple, these tubes dilate into

Fig. 183.



Distribution of the *Milk-ducts* in the Mamma of the Human female, during lactation; the ducts injected with wax.

reservoirs, which extend beneath the areola and to some distance into the gland, when the breast is in a state of lactation. These are much larger in many of the lower Mammalia, than they are in the Human female;

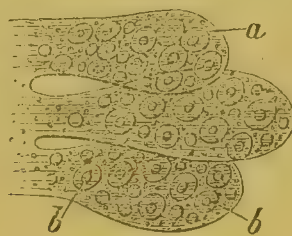
* "On the Anatomy of the Breast," 1840.
† "The Diseases of the Breast, and their Treatment," 1850.

ıeir use is to supply the immediate wants of the child when it is first ɔplied to the breast, so that it shall not be disappointed, but shall be .duced to proceed with sucking until the 'draught' be occasioned (§ 948). rom each of these reservoirs commence five or six branches of the *ctiferous tubes*, each of which speedily subdivides into smaller ones; and ıese again divaricate, until their size is very much reduced, and their :tent greatly increased (Fig. 183). These, like the reservoirs and mam-illary tubes, are composed of a fibrous coat lined by a mucous mem-ane; the latter is highly vascular, and forms a secretion of its own, which metimes collects in considerable quantity when the milk ceases to be ·oduced. The smaller subdivisions of the lactiferous tubes proceed to dis-nct lobuli in each glandule; so that when a branch of a mammary tube ıs been filled with injection, its attached lobules, if separated from each her by long maceration, are like a bunch of fruits clustered upon a stalk 'ig. 184). When the lactiferous tubes are pursued to their ultimate distri-ıtion, they are found to terminate in follicles, whose size, in full lacta-ɔn, is that of a hole pricked in paper by the point of a very fine pin, so at when distended with quicksilver or milk, they are just visible to the .ked eye; at other times, however, the follicles do not admit of being jected, though the lactiferous tubes may have been completely filled.

FIG. 184.

Termination of portion of *Milk-duct* in a *cluster of follicles;* from a mercurial injection; enlarged four times.

FIG. 185.




*Ultimate follicles* of Mammary gland, with their secreting cells, *a*, *a*;—*b*, *b*, the nuclei.

.ey are lined by a continuation of the same membrane, with that which es the ducts; and this possesses a high vascularity. The arteries .ich supply the glandules with blood, become very large during lacta-n; and their divisions spread themselves minutely on the follicles. om the blood which they convey, the milk is secreted and poured into ɜ follicles, whence it flows into the ducts. The inner surface of the lk-follicles, in common with other glandular structures, is covered with ayer of epithelium-cells (Fig. 185), as was first observed by Prof. Good-; and these, being seen to contain milk-globules, may without doubt be ;arded as the real agents in the secreting process. Absorbent vessels : seen to arise in large numbers in the neighbourhood of the follicles; ɜir function appears to be, to absorb the more watery part of the milk ıtained in the follicles and tubes, so as to render it more nutrient than s when first secreted; and also to relieve the distension which would :ur, during the absence of the child, from the continuance of the reting process.—The Mammary gland may be detected at an early 'iod of fœtal existence; being easily distinguishable from the surround-: parts, by the redness of its colour and its high vascularity, especially

when the whole is injected. At this period, it presents no difference in the male and female; and it is not until near the period of puberty that any striking change manifests itself, the gland continuing to grow, in the one sex as in the other, in proportion to the body at large. At about the age of thirteen years, however, the enlargement of the gland commences in the Female; and by sixteen, it is greatly evolved, and some of the lactiferous tubes can be injected. At about the age of twenty, the gland attains its full size previous to lactation; but the milk-follicles cannot even then be injected from the tubes. During pregnancy, the mammæ receive a greatly-increased quantity of blood. This determination often commences very early, and produces a feeling of tenderness and distension, which is a valuable sign (where it exists in connection with others) of the commencement of gestation. The Areola at this time becomes darker in its colour, and thicker in substance, and also more extended; its papillæ become more developed, and the secretion from its follicles increases. A true lacteal secretion usually commences about the third or fourth month of pregnancy, and may be obtained by pressure properly applied. This fact may be usefully applied in diagnosing cases of concealed or doubtful pregnancy from cases of simple suppression of the catamenia; but it will not serve to distinguish true pregnancy from spurious, or from the distension of the uterus by tumours.* The vascularity of the gland continues to increase during pregnancy; and at the time of parturition, its lobulated character can be distinctly felt. The follicles are not, however, developed sufficiently for injection, until lactation has commenced. After the cessation of the catamenia from age, so that pregnancy is no longer possible, the lactiferous ducts continue open, but the milk-follicles are incapable of receiving injection. The substance of the glandules gradually disappears, so that in old age only portions of the ducts remain, which are usually loaded with mucus; but the place of the glandules is commonly filled up by adipose tissue, so that the form of the breast is preserved. Sir A. Cooper notices a curious change, which he states to be almost invariable with age; namely, the ossification of the arteries of the breast, the large trunks as well as the branches, so that their calibre is greatly diminished or even obliterated.—The Mammary gland of the Male is a sort of miniature picture of that of the Female. It varies extremely in its magnitude, being in some persons of the size of a large pea; whilst in others it is an inch, or even two inches, in diameter. In its structure it corresponds exactly with that of the female, but is altogether on a smaller scale. It is composed of lobules containing follicles, from which ducts arise; and these follicles and ducts are not too minute to be injected, although with difficulty. The evolution of the gland goes on *pari passu* with that of the body, not undergoing an increase at any particular period; it is sometimes of considerable size in old age. A fluid, which is probably mucus, may be pressed from the nipple in many persons; and this in the dead body, with even more facility than in the living. That the essential character of the gland is the same in the male as in the female, is shown by the instances, of which there are now several on record, in which infants have been suckled by men (§ 1022).

* See the valuable paper by Dr. Peddie, 'On the Mammary Secretion,' in the "Edinb. Monthly Journ.," Aug. 1848.

1022. Although the state of functional activity in the Mammary gland .s usually limited to the epoch succeeding Parturition, yet this is not invariably the case; for numerous instances are on record, in which young women who have never borne children, and even old women long past the period of child-bearing, have had such a copious flow of milk as to be able to act as efficient nurses.* In these cases, the strong desire to furnish milk, and continued irritation of the nipple by the infant's nouth, seem to have furnished the stimulus requisite for the formation of the secretion; and it has been found that this is usually adequate to *restore* the secretion, after it has been intermitted for some months during the ordinary period of lactation, in consequence of disorder or debility on the part of the mother, or any other cause; so that where her condition renders it advisable that she should discontinue nursing for a time, the child may be withdrawn and the milk 'dried-up,' with a confident expectation that the secretion may be reproduced subsequently.† Dr. M'William mentions in his Report of the Niger Expedition,‡ that the inhabitants of Bona Vista (Cape de Verde Islands) are accustomed to provide a wet-nurse in cases of emergency, in the person of any woman who has once borne a child and is still within the age of child-bearing, by continued fomentation of the mammæ with a decoction of the leaves of the *jatropha curcas,* and by suction of the nipple. The most curious fact, however, is that even *Men* should occasionally be able to perform the duties of nurses, and should afford an adequate supply of infantile nutriment. Several cases of this kind are upon record;§ but one of the most recent and authentic is that given by Dr. Dunglison.|| "Professor Hall, of the university of Maryland, exhibited to his Obstetrical class, in the year 1837, a coloured man, fifty-five years of age, who had large, soft, well-formed mammæ, rather more conical than those of the female, and projecting fully seven inches from the chest; with perfect and large nipples. The glandular structure seemed to the touch to be exactly like that of the female. This man had officiated as wet nurse, for several years, in the family of his mistress; and he represented that the secretion of milk was induced by applying the children entrusted to his care, to the breasts, during the night. When the milk was no longer required, great difficulty was experienced in arresting the secretion. His genital organs were fully developed."—Corresponding facts are also recorded of the male of several of the lower animals.

1023. The secretion of *Milk* consists of Water holding in solution

* A collection of such cases is given in Dr. Dunglison's "Human Physiology," 7th edit., vol. ii. p. 513.

† See an account of M. Trousseau's experience on this point, in "L'Union Médicale," 1852, No. 7; and a paper by Dr. Ballou in the "Amer. Journ. of Med. Sci.," Jan. 1852.

‡ "Medical Gazette," Jan. 1847.

§ See the case described by the Bishop of Cork, in the "Philosophical Transactions," vol. xli. p. 813: one mentioned by Captain Franklin ("Narrative of a Journey to the Polar Sea," p. 157); and one which fell under the notice of the celebrated traveller Humboldt ("Personal Narrative," vol. iii. p. 58).

|| "Human Physiology," 7th edit., vol. ii. p. 514.—Dr. Dunglison also mentions that in the winter of 1849-50, an athletic man, twenty-two years of age, presented himself at the Jefferson Medical College at Philadelphia; whose left mamma, *without any assignable cause,* became greatly developed, and secreted milk copiously.—It may be added that a lactescent fluid, apparently presenting the characters of true milk, may frequently be expressed from the mammary glands of infants. (See "Dublin Medical Press," April 17, 1850).

Sugar, various Saline ingredients, and the peculiar albuminous substance termed Casein; and having Oleaginous particles suspended in it. The constitution of this fluid is made evident by the ordinary processes to which it is subjected in domestic economy. If it be allowed to stand for some time, exposed to the air, a large part of the oleaginous globules come to the surface, being of less specific gravity than the fluid through which they are diffused. At the same time, there is reason to believe that they undergo a change, which will be presently described. The *cream* thus formed does not, however, consist of oily particles alone; but includes a considerable amount of casein, with the sugar and salts of the milk. These are further separated by the continued agitation of the cream; which, by rupturing the envelopes of the oil-globules, separates it into *butter*, formed by their aggregation, and *buttermilk*, containing the casein, sugar, &c. A considerable quantity of casein, however, is entangled with the oleaginous matter, and this has a tendency to decompose, so as to render the butter rancid; it may be separated by keeping the butter melted at the temperature of 180°, when the casein will fall to the bottom, leaving the butter pure and much less liable to change.—The milk, after the cream has been removed, still contains the greatest part of its casein and sugar. If it be kept long enough, a spontaneous change takes place in its composition; the sugar is converted into lactic acid, and this coagulates the casein, precipitating it in small flakes. The same precipitation may be accomplished at any time, by the addition of an acid; all the acids, however, which act upon albumen, do not precipitate casein, as will presently be pointed out in detail; the most effectual is that contained in the dried stomach of a calf, known as *rennet.* The whey left after the curd has been separated, contains a large proportion of the saccharine and saline matter that entered into the original composition of the milk; this may be readily separated by evaporation.—When Milk is examined with the Microscope, it is seen to contain a large number of particles of irregular size and form, suspended in a somewhat turbid fluid; these particles vary in size from about the 1-12,700th to the 1-3040th of an inch; and they are termed 'milk-globules.' They are not affected by the mere contact of ether or alkalies; but if these reagents are shaken with them, an immediate solution is the result. The same effect happens, if they are first treated with acetic acid. Hence it is evident, that the globules consist of oily matter, inclosed in an envelope of some kind: and an extremely delicate pellicle may, in fact, be distinguished, after the removal of the oily matter by ether, or after the globules have been ruptured and their contents pressed-out by rubbing a drop of milk between two plates of glass. No proof of the organization of this pellicle has, however, been detected; and it is probably to be regarded as the simple result of the contact of oil with albuminous matter (§ 42).—Besides these milk-globules, other globules of much smaller size are seen in milk; and these present the peculiar movement which is exhibited by molecules in general. Most of them seem to consist of oily matter not enclosed in an envelope, as they are at once dissolved when the fluid is treated with ether; but, according to the statements of Donné, it would seem that a portion of them are composed of casein, suspended, not dissolved, in the fluid. In addition to the foregoing particles, there are found in the

Colostrum, or milk first secreted after delivery, large yellow granulated corpuscles, which seem to be composed of a multitude of small grains aggregated together; these appear to be chiefly of a fatty nature, being for the most part soluble in ether; but traces of some adhesive matter, probably mucus, holding together the particles, are then seen. They are considered by some as 'exudation-corpuscles,' to which they certainly bear a close resemblance; according to Reinhardt, they are transformations of the epithelial cells of the mammary ducts, the result of a sort of fatty degeneration or regressive metamorphosis consequent upon the peculiar activity of the mammary gland during pregnancy.* Lamellæ of epithelium are also found in the milk.—All the larger globules may be removed by repeated filtration; and the fluid is then nearly transparent. This, in fact, is the simplest way of separating the oleaginous from the other constituents of the milk; as but little casein then adheres to the former. That the transparent fluid which has passed through the filter contains nearly the whole amount of the casein of the milk, appears a sufficient proof that this is, for the most part, truly dissolved in the fluid.

1024. We shall now consider the chemical characters of each of the foregoing ingredients.—The *Oleaginous* matter of milk principally consists of the ordinary components of fat (§ 37); but it also contains another substance peculiar to it, designated as *butyrin*, to which the peculiar smell and taste of butter are due; this yields in saponification three volatile acids, of strong animal odour, to which Chrevreul has given the names of butyric, caproic, and capric acids. These peculiar acids are not only formed when the butyrin is treated with alkalies; but are produced by the ordinary decomposition of this principle, which is favoured by time and moderate warmth.—The *Casein* of Human milk, however, is usually said to be much less precipitable by acids, than is that of the Cow; very commonly resisting the action of the mineral acids, and even that of the acetic; but being always coagulated by rennet, though the curd is long in collecting. On this point, however, there has been much discrepancy of statement, on which the recent experiments of Mr. Moore † throw some light. It appears from the results obtained by him, that Human Milk forms with most acids two sets of compounds, one of them soluble in water, the other insoluble; the latter being formed only when the quantity of acid is large in proportion to the casein. Thus, when two fluid *ounces* of Cow's milk were boiled with a single drop of nitric acid, complete coagulation of the casein at once took place: but when two fluid *drachms* of Human milk were treated in the same manner, no coagulation occurred, though the casein was at once thrown down by a solution of ferrocyanide of potassium; the same quantity of milk, with five drops of the acid, formed a coagulum which was not very manifest until after the lapse of five hours, but was very complete, the serous fluid not being found to contain any casein by testing it with ferrocyanide of potassium; and it required ten drops of nitric acid to produce immediate coagulation.—The quantity of acid necessary to produce coagulation sufficiently rapid to be immediately

* See an abstract of his views in the "Edinb. Monthly Journal," for Feb. 1848.
† "Dublin Quarterly Journal of Medical Science," vol. vii. p. 280.

visible, will vary with the amount of casein present in the particular specimen of milk, 5 drops in some instances producing a coagulation as rapid as that produced by 10 drops in others. In no specimen did Mr. Moore fail to produce coagulation by adding a sufficiency of acid. Acetic acid without heat produces in Human milk a slow separation of soft flaky coagula; but, when heat is employed, a more perfect coagulation is produced by small, than by large quantities of this acid. Rennet does not seem to act upon the casein of Human milk, unless an acid be also present. In several of these particulars, as well as in its small proportional amount, the Casein of Ass's milk bears a closer resemblance to that of Human milk, than does that of the Cow.—The *Sugar of Milk*, which may be obtained by evaporating whey to the consistence of a syrup, and then setting it aside to crystallize, forms opaque prisms or rhombohedra, whose composition is 10 C, 8 H, 8 O + 2 HO. In many of its properties it bears a close resemblance to Glucose (§ 45), into which it is readily converted by the agency of dilute sulphuric or hydrochloric acid, or by the acetic or citric acids. It is readily made to pass into the lactic and butyric fermentation, by the appropriate ferments; but is with difficulty brought to undergo the vinous fermentation.—The *Saline* matter contained in milk, appears to be nearly identical with that of the blood; with a larger proportion of the phosphates of lime and magnesia, which amount to 2 or $2\frac{1}{2}$ parts in 1000. These phosphates are held in solution chiefly by the casein, which seems to have a power of combining with them, even greater than that of albumen: the presence of a minute proportion of free alkali, also, assists their solution. A small portion of iron in the state of phosphate, together with the chlorides of potassium and sodium, may also be detected in milk.*

1025. The proportion of these different constituents is liable to great variation, from several causes. Thus, the whole amount of the solid constituents may vary from 86 to 138·6 parts in 1000; the difference being partly due to individual constitution, but in great part, also, to the amount and character of the ingesta. The average seems to be between 100 and 120 parts. The following are the results of the analyses of Simon; the first column being the average of fourteen observations upon the same woman; the second giving the maximum of each ingredient; and the third the minimum:—

| | I. | II. | III. |
|---|---|---|---|
| Water | 883·6 | 914·0 | 861·4 |
| Butter | 25·3 | 54·0 | 8·0 |
| Casein | 34·3 | 45·2 | 19·6 |
| Sugar of Milk and extractive matters | 48·2 | 62·4 | 39·2 |
| Fixed salts | 2·3 | 2·7 | 1·6 |

It also appears from the analyses of Simon, that the proportion of the different ingredients is liable to variation, according to the time which has elapsed since parturition. The quantity of Casein is at its minimum at the commencement of lactation, and then gradually rises until it attains a nearly fixed proportion. The quantity of Sugar, on the contrary, is at its maximum at first, and gradually diminishes. The amount of Butter (as appears from the wide extremes shown in the above tables) is more variable than that of any other constituent.—That some of the variations are due, moreover, to the character of the ingesta, and others to the

* Haidlen in "Annalen der Chemie und Pharmacie," band xlv. p. 263.

external temperature, amount of exercise, and other circumstances affecting the individual, is proved by the inquiries of Dr. Playfair upon the Milk of the Cow. He has shown that the amount of butter depends in part upon the quantity of oily matter in the food, and in part upon the amount of exercise which the animal takes, and the warmth of the atmosphere in which it is kept: exercise and cold, by increasing the respiration, eliminate part of the oily matter in the form of carbonic acid and water; whilst rest and warmth, by diminishing this drain, favour its passage into the milk. The proportion of Casein, on the other hand, is increased by exercise. Dr. Playfair's experience on this head seems to correspond with the results of common observation in Switzerland; for where the cattle pasture in very exposed situations, and are obliged to use a great deal of muscular exertion, the quantity of butter yielded by them is very small, whilst the cheese is in unusually large proportion; but these very cattle, when stall-fed, give a large quantity of butter and very little cheese.

1026. The change which naturally takes place, from the condition of Colostrum to that of true Milk, during the first week of lactation, is a very important one. The Colostrum has a purgative effect upon the child, which is very useful in clearing its bowels of the meconium that loads them at birth; and thus the necessity of any other purgative is generally superseded. Occasionally, however, the *colostric* character is retained by the milk, during an abnormally long period; and the health of the infant is then severely affected. It is important to know that this may occur, even though the milk may present all the usual appearance of the healthy secretion; but the microscope at once detects the difference.* The return to the character of the early milk, which has been stated to take place after the expiration of about twelve months, seems to indicate that Nature designs the secretion no longer to be encouraged. The mother's milk cannot then be so nutritious to the child as other food;† and every medical man is familiar with the injurious consequences to which she renders herself liable, by unduly prolonging lactation.‡ Cases are not unfrequent, however, in which the secretion continues as long as there is a demand for it; and sometimes quite independently of this. It is the habit, among some nations, to suckle the children until they are three or four years old, and to continue doing so even though another pregnancy should supervene;§ so that the older child is only displaced by the arrival of another infant. And it seems to be chiefly among those who have thus forced the mammary gland into a state of unnaturally persistent activity, that the spontaneous and irrepressible flow continues, after the demand for it has ceased.||

1027. It is very interesting to observe that Milk contains the three classes of principles which are required for human food,—the Albuminous,

* See Donné, "Du Lait, et en particulier celui des Nourrices" and "Brit. and For. Med. Review," vol. vi. p. 181.

† On the whole subject of Infant Nutrition, the Author would strongly recommend the excellent little work of Dr. A. Combe, formerly referred-to.

‡ One of these, which has particularly fallen under the Author's notice, is debility of the retina, sometimes proceeding to complete amaurosis; this, if treated in time, is most commonly relieved by discontinuance of lactation, generous diet, and quinine.

§ See Erman's "Travels in Siberia" (translated by Cooley), vol. ii. p. 527; and the "Narrative of the United States' Exploring Expedition," vol. ii. p. 138.

|| Thus Dr. Green has published ("New York Journ. of Med. and Surg.," Sept. 1844)

the Oleaginous, and the Saccharine; and it is the only secreted fluid in which these all exist to any considerable amount. It is, therefore, the food most perfectly adapted for the young animal; and is the only single article supplied by nature, in which such a combination exists. Our artificial combinations will be suitable to replace it, just in proportion as they imitate its character; but in none of them can we advantageously dispense with milk, under some form or other. It should be remembered that the Saline ingredients of milk, especially the phosphates of lime, magnesia, and iron, have a very important function in the nutrition of the infant, affording the material for the consolidation of its bones and for the production of its red blood-corpuscles; and any fluid substituted for milk, which does not contain these, is deficient in essential constituents. It is very justly remarked by Dr. Rees,* that, of all the secreted fluids, Milk is most nearly allied in its composition to Blood.

1028. The proportion of the different ingredients in the Milk of different animals, is subject to considerable variation : and this fact is of much practical importance in guiding our selection, when good Human milk cannot be conveniently obtained for the nourishment of an infant. The first point to be inquired into, is the quantity of solid matter contained in each kind; this may be determined either by evaporation, or by the specific gravity of the fluid. The Specific Gravity of Human milk is stated by Dr. Rees (loc. cit.) to vary between 1030 and 1035; others, however, have estimated it much lower. That of the Cow appears to be usually about the same; that of the cream, however, being 1024, and that of the skimmed milk about 1035. The variation will in part depend (as in the case of the urine) upon the quantity of fluid ingested, and in part, it is probable, upon the manner in which the milk is drawn; for it is well known to milkers, that the last milk they obtain is much richer than that with which the udder is distended at the commencement. The quantity of solid matter obtainable from Human and from Cow's Milk by evaporation, seems, like the specific gravities of the fluids, to be nearly the same. In the relative proportion of the ingredients, however, there is a considerable difference; there being much more sugar and less casein in Human Milk, than in that of the Cow. The following table exhibits the relative proportions of the different ingredients, in the Milk of various animals from which that fluid is commonly obtained :—

| | Cow. | Goat. | Sheep. | Ass. | Mare. |
|---|---|---|---|---|---|
| Water . . . . | 861·0 | 868·0 | 856·2 | 907·0 | 896·3 |
| Butter . . . | .38·0 | 33·2 | 42·0 | 12·10 | traces |
| Casein . . . . | 68·0 | 40·2 | 45·0 | 16·74 | 16·2 |
| Sugar of Milk and extractive matters | 29·0 | 52·8 | 50·0 | 62·31 | 87·5 |
| Fixed salts . . . | 6·1 | 5·8 | 6·8 | | |

It appears from this, that, whilst the milks of the Cow, Goat, and Sheep do not differ from each other in any very prominent degree, that of the Ass and Mare is a fluid of very dissimilar character, containing a comparatively small proportion of casein, and scarcely any butter, but abounding in sugar. Hence it is, that it is much more disposed to ferment than

the case of a lady, æt. 47, the mother of four children, who had an abundant supply of milk for *twenty-seven years* previously. A period of exactly four years and a half occurred between each birth, and the children were permitted to take the breast until they were running about at play. At the time when Dr. G. wrote, she had been nine years a widow, and was obliged to have her breasts drawn daily, the secretion of milk being so copious.

* "Cyclopædia of Anatomy and Physiology," Art. 'Milk.'

other milk; indeed the sugar of mare's milk is so abundant, that the Tartars prepare from it a spirituous liquor, to which they give the name of *koumiss.* It would further appear that no milk more nearly approaches that of the Human female, in the proportion of its ingredients, than that of the Sheep and Goat; these both possess, however, a larger amount of casein, which forms a peculiarly dense curd; and the milk of the goat is tainted with the peculiar odour of the animal, which is more intense if the individual be dark-coloured. The milk of the Ass, though differing in the proportion of its ingredients, seems to bear a closer approximation in properties (§ 1024). The milk of the Cow will usually answer very well for the food of the infant; care being taken to dilute it properly, according to the age of the child, and to add a little sugar. Where there is an apprehension of an early failure in the supply of Milk, the Author has found it advantageous to commence feeding the Infant once a day with this mixture, soon after the first month; and the number of its meals may be progressively increased, until it becomes entirely independent of its parent, without any abrupt transition.

1029. From what has been stated of the close correspondence between the elements of the Blood and those of the Milk, it is evident that we can scarcely expect to trace the existence of the latter, as such, in the circulating fluid. To what degree the change in which their elaboration consists, is accomplished in the Mammary gland, or during the course of the circulation, there is no certain means of ascertaining. It is evident that this secretion cannot serve as the channel for the deportation of any element, the accumulation of which would be injurious to the system; since it does not occur in the male at all, and is present in the female at particular times only. Yet there is reason to believe that if, whilst the process is going on, it be suddenly checked, the retention of the material in the blood, or the re-absorption of the secreted fluid, is attended with injurious consequences. Thus if, when the milk is first secreted, the child be not put to the breast, an accumulation takes place, which, if not relieved, occasions great general disturbance of the system. The narrowness of the orifices of the milk-tubes obstructs the spontaneous exit of the fluid, especially in *primiparæ;* the reservoirs and ducts become loaded; further secretion is prevented; and a state of congestion of the vessels of the gland, tending to inflammation, is induced. The accompanying fever is partly due, no doubt, to the local disturbance; but in part also, there seems reason to believe, to the re-absorption of the milk into the blood; this cannot but be injurious, since, although but little altered, the constitution of milk is essentially different, especially in regard to the quantity of crystallizable matter (sugar) which it contains.—The instances of the vicarious secretion of milk are not numerous; and in no instance is there any proof that the elements of the fluid were pre-existent in the blood. Some of the most curious are those in which it has been poured out from a gland in the groin; but it is probable that this was in consequence of the existence of a real repetition, in that place, of the true mammary structure; this being the situation of the mammæ of many of the inferior animals, of which the homologues in Man are usually undeveloped.*

* The following is a more unequivocal case of vicarious secretion; and it is peculiarly interesting as exhibiting the injurious effects of the re-absorption of the secretion, and the relief which the system experienced when it was separated from the blood by the new channel.

1030. Of the quantity of Milk ordinarily secreted by a good Nurse, it is difficult to form a correct estimate;* since the amount which can be artificially drawn, affords no criterion of that which is secreted at the time of the 'draught' (§ 948). The quantity which can be squeezed from either breast at any one time, and which, therefore, must have been contained in its tubes and reservoirs, is about two ounces. The amount secreted is greatly influenced by the mental and physical condition of the female, and also by the quantity and character of the ingesta. In regard to the influence of the mental state upon this secretion, ample details have already been given (CHAP. XVIII.) With respect to the physical state most favourable to the production of an ample supply of this important fluid, it may be stated generally, that sound health, a vigorous but not plethoric constitution, regular habits, moderate but not fatiguing exercise, and an adequate but not excessive amount of nutritious food, furnish the conditions most required. It is seldom that stimulating liquors, which are so commonly indulged-in, are anything but prejudicial; but the unmeasured condemnation of them in which some writers have indulged, is certainly injudicious; as experience amply demonstrates the improvement in the condition both of mother and infant, which occasionally results from the moderate employment of them. Their *modus operandi*, when they are really beneficial, seems to lie in promoting the digestive process, and in thus aiding in the appropriation of those nutritive materials, which constitute the real source of the solid constituents of the milk.—The influence of various Medicines upon the Milk, is another important question which has not yet been sufficiently investigated. As a general rule, it appears that the most soluble saline compounds pass into the milk as into other secretions; but there are many exceptions. Common salt, the sesqui-carbonate of soda, sulphate of soda, iodide of potassium, oxide of zinc, tris-nitrate of bismuth, and sesqui-oxide of iron, have been

"A lady of delicate constitution (with a predisposition to pneumonia) was prevented from suckling her child, as she desired, by the following circumstance. Soon after her delivery she had a severe fever, during which her breasts became very large and hard; the nipples were swollen and firm; and there was evidently an abundant secretion of milk; but neither the sucking of the infant, nor any artificial means, could draw a single drop of fluid from the swollen glands. It was clear that the milk-tubes were closed; and as the breasts continued to grow larger and more painful, purgatives and other means were employed to check the secretion of milk. After three days the fever somewhat diminished, and was replaced by a constant cough, which was at first dry, but soon after was followed by the expectoration of simple mucus. After this, the cough diminished in severity, and the expectoration became easy; but the sputa were no longer mucous, but were composed of a liquid, which had all the physical characters of genuine milk. This continued for fifteen days; the quantity of milk expectorated amounting to three ounces or more in the twenty-four hours. The breasts gradually diminished in size: and by the time that the expectoration ceased, they had regained their natural dimensions. The same complete obstacle to the flow of milk from the nipples recurred after the births of four children successively, with the same sequelæ. After the sixth, she had the same symptoms of fever, but this time they were not followed by bronchitis or the expectoration of milk; she had in their stead copious sweatings, which, with other severe symptoms, reduced her to a cachectic state, and terminated fatally in a fortnight." ("Bulletino delle Scienze Mediche," Apr. 1839; and "Brit. and For. Med. Review," Jan. 1840.)

* For an estimate by M. Guillot, founded on the comparative weight of the Infant before and after lactation, see "L'Union Médicale," 1852, No. 16. The total amount considered by Mons. G. to be usually drawn in the twenty-four hours, varies from 32 oz. to 64 oz. (Apoth.); but his estimates are vitiated by the extraordinary frequency of the lactations observed, the infant being put to the breast from 25 to 30 times in the twenty-four hours.

readily detected in the milk, when these substances were experimentally administered to an Ass; and ordinary experience shows, that the Human infant is affected by many of these, when they are administered to the mother. The influence of mercurial medicines taken by the mother, in removing from the infant a syphilitic taint possessed by both, is also well known. The vegetable purgatives, especially castor-oil, senna, and colocynth, have little effect upon the milk; hence they are to be preferred to the saline aperients, when it is not desired to act upon the bowels of the child.

## CHAPTER XX.

### OF THE DIFFERENT BRANCHES OF THE HUMAN FAMILY, AND THEIR MUTUAL RELATIONS.

#### 1. *General Considerations.*

1031. Amongst the various tribes of Men, which people the surface of the globe, and which are separated from all other animals by the characters formerly described (Chap. I.) there are differences of a very striking and important nature. They are distinguishable from each other, not merely by their language, dress, manners and customs, religious belief, and other acquired peculiarities, but in the physical conformation of their bodies; and the difference lies, not merely in the colour of the skin, the nature of the hair, the form of the soft parts (such as the nose, lips, &c.), but in the shape of the skull, and of other parts of the bony skeleton, which might be supposed to be less liable to variation. It is a question of great scientific interest, as well as one that considerably affects the mode in which we regard the races that differ from our own, whether they are all of *one species*, that is, descended from the *same* or from *similar* parentage,—or whether they are to be considered as *distinct species*, the first parents of the several races having had the same differences among themselves, as those which are now exhibited by their descendants.

1032. In order to arrive at a just conclusion on this subject, it is necessary to take a very extensive survey of the evidence furnished by a number of different lines of inquiry. Thus, in the first place, it is right to investigate what are the discriminating structural marks, by which *species* are distinguished among other tribes of animals.—Secondly, it should be ascertained to what extent *variation* may proceed among races which are historically known to have a common parentage, and what are the circumstances which most favour such variations.—Thirdly, the extreme variations, which present themselves among the different races of Men, should be compared with those which occur among tribes of animals known to be of the same parentage; and it should be questioned, at the same time, whether the circumstances which favour the production of varieties in the latter case, are in operation in the former.—Fourthly, where it is impossible to trace back distinct races to their origin, it is to be inquired how far agreement in physiological and psychological peculiarities may be regarded as indicating specific identity, even where a considerable difference exists in bodily conformation; and this test, if it can

be determined-on, has to be applied to Man.—Fifthly, it must be attempted, by a detailed examination of the varieties of the Human race themselves, to ascertain whether their differences in conformation are constant; or whether there are not occasional manifestations, in each race, of a tendency to assume the characters of others; so as to prevent any definite lines being drawn between the several tribes, which together make-up the (supposed) distinct species.—An investigation so comprehensive could not be followed-out, even in the most cursory manner that would be consistent with utility, within the limits of the present work; and no more will be attempted, therefore, than an indication of the principal points of difference among the several Races of Men, and a statement of the results of inquiry into their degree of constancy in each group which they can be used to separate.*

1033. The differential characters on which those have relied, who have sought to establish the existence of a *plurality of species* among Mankind, are both Anatomico-Physiological, and Psychological. Under the former head rank the Colour of the Skin, the texture of the Hair, and the conformation of the bony Skeleton, especially the Skull. The latter consist in the superiority claimed for some races over others, in intellectual power, and in moral and religious capacity. The former group will be the one first considered.

1034. The *Colour* of the skin exists in the Epidermis only; and it depends upon the admixture of *pigment-cells* with the ordinary epidermic cells (§ 242); all the varied hues presented by the different races of men, being due to the relative amount of these cells, and to the particular tint of the pigment which they form. It would be easy, by selecting well-marked specimens of each race, to make it appear that colour affords a character sufficiently distinctive for their separation; thus, for example, the fair and ruddy Saxon, the jet-black Negro, the olive Mongolian, and the copper-coloured North American, might be considered to be positively separated from each other by this character,—propagated, as it seems to be, with little or no perceptible change, from generation to generation. But although such might appear to be the clear and obvious result of a comparison of this kind, yet a more profound and comprehensive survey tends to break-down the barrier that would be thus established. For, on tracing this character through the entire family of Man, we find the isolated specimens just noticed to be connected by such a series of links, and the transition from one to the other to be so very gradual, that it is impossible to say where the line is to be drawn. There is nothing here, then, which at all approaches to those fixed and definite marks, that are always held to be requisite for the establishment of specific distinctions among other tribes of animals.

1035. But further, there is abundant evidence that these distinctions are far from being constantly maintained, even in any one race. For among all the principal subdivisions, *albinoism*, or the absence of pigment-cells, occasionally presents itself; so that the fair skin of the European

* The whole of this investigation has been most elaborately, and in the Author's opinion most successfully, worked out by Dr. Prichard, in his profound and philosophical Treatise on the "Physical History of Man." For a more concise view of Dr. Prichard's argument, with some additional considerations not embraced in it, the Author may refer to his own Article on the 'Varieties of the Human Species,' in the "Cyclop. of Anat. and Phys.," vol. iv.

may present itself in the offspring of the Negro or of the Red Man.* On the other hand, instances are by no means rare, of the unusual development of pigment-cells in individuals of the fair-skinned races; so that parts of the body are of a dark red or brown hue, or are even quite black. Such modifications may seem of little importance to the argument; since they are confined to individuals, and may be put aside as accidental. But there is ample evidence that analogous changes may take place in the course of time, which tend to produce a great variety of shades of colour, in the descendants of any one stock. Thus, in the great Indo-European family (part of the *Caucasian* race of Blumenbach), which may be unquestionably regarded as having had a common origin, we find races with fair complexion, yellow hair, and blue eyes,—others presenting the xanthous or olive hue,—and others decidedly black. A similar diversity may be seen among the American races, which are equally referable to one common stock; and it exists to nearly the same extent among the African nations, which are similarly related to each other. It may be freely admitted that, among European colonists settled in hot climates, such changes do not present themselves within a few generations; but in many well-known instances of earlier colonization, they are very clearly manifested. Thus the wide dispersion of the Jewish nation, and their remarkable isolation (maintained by their religious observances) from the people among whom they live, render them peculiarly appropriate subjects for such observations; and we accordingly find that the brunette complexion and dark hair, which are usually regarded as characteristic of that race, are frequently superseded, in the Jews of Northern Europe, by red or brown hair and fair complexion; whilst the Jews who settled in India some centuries ago, have become as dark as the Hindoos around them.

1036. The relation of the complexions of the different races of Men to the climates they respectively inhabit, is clearly established by an extended comparative survey of both. From such a survey the conclusion is inevitable, that the intertropical region of the earth is the principal seat of the darkest races of Men; whilst the region remote from the tropics is that of the fairer races; and that the climates approaching the tropics are generally inhabited by nations which are of an intermediate complexion. To this observation it may be added, that high mountains, and countries of great elevation, are generally inhabited by people of a lighter colour than are those of which the level is low, such as swampy or

* A very curious example of *change of colour* in a Negro, has been recently recorded on unquestionable authority.—The subject of it is a negro slave in Kentucky, æt. 45, who was born of black parents, and was himself perfectly black until 12 years of age. At that time, a portion of the skin, an inch wide, encircling the cranium just within the edge of the hair, gradually changed to white; also the hair occupying that locality. A white spot next appeared near the inner canthus of the left eye; and from this the white colour gradually extended over the face, trunk, and extremities, until it covered the entire surface. The complete change from black to white occupied about ten years; and but for his hair, which was crisped or woolly, no one would have supposed at this time that his progenitors had offered any of the characteristics of the Negro, his skin presenting the healthy vascular appearance of that of *a fair-complexioned* European. When he was about 22 years of age, however, dark *copper-coloured* or brown spots began to appear on the face and hands; but these have remained limited to the portions of the surface exposed to light.—About the time that the black colour of his skin began to disappear, he completely lost his sense of smell; and since he has become white, he has had measles and hooping-cough a second time. (See Dr. Hutchison's account of this case, in the "Amer. Journ. of Med. Sci.," Jan. 1852.)

sandy plains upon the sea-coast. These distinctions are particularly well seen in Africa, where the tropics almost exactly mark out the limits of the black complexion of the inhabitants; and where the deepest hue is to be seen among the Negroes of the Guinea Coast, whose residence unites both the conditions just mentioned; whilst the mountainous regions in their immediate vicinity are inhabited by tribes of a much lighter aspect.

1037. The nature of the *Hair* is, perhaps, one of the most permanent characteristics of different races. In regard to its colour, the same statements apply as those just made with respect to the colour of the skin; the variety of hue being given by pigment-cells, which may be more or less developed under different circumstances. But it has been thought that its *texture* afforded a more valid ground of distinction; and it is commonly said, that the substance which grows on the head of the African races, and of some other dark-coloured tribes (chiefly inhabiting tropical climates), is *wool*, and not hair. This, however, is altogether a mistake; for microscopic examination clearly demonstrates, that the hair of the Negro * has exactly the same structure with that of the European; and that it does not bear any resemblance to wool, save in its crispness and tendency to curl. Moreover, even this character is far from being a constant one; for, whilst Europeans are not unfrequently to be met with, whose hair is nearly as crisp as that of the Negro, there is a great variety amongst the Negro races themselves, which present every gradation from a completely crisp (or what is termed woolly) hair, to merely curled or even flowing locks. A similar observation holds good in regard to the natives of the islands of the great Southern Ocean, where some individuals possess crisp hair, whilst others, of the same race, have it merely curled.—It is evident, then, that no characters can be drawn from the colour or texture of the hair in Man, sufficiently fixed and definite to serve for the distinction of races; and this view is borne out by the evident influence of climate, in producing changes in the hairy covering of almost every race of domestic animals; such changes often manifesting themselves in the very individuals that have been transported from one country to another, and yet more distinctly in succeeding generations.

1038. It has been supposed that varieties in the configuration of the *Skeleton* would afford characters for the separation of the Human races, more fixed and definite than those derived from differences in the form, colour, or texture of the soft parts which clothe it. And attention has been particularly directed to the *skull* and the *pelvis*, as affording such characters. It has been generally laid down as a fundamental principle, that all those nations which are found to resemble each other in the shape of their heads, must needs be more nearly related to each other, than they are to tribes of Men which differ from them in this particular. But if this principle be rigorously carried-out, it will tend to bring together races which inhabit parts of the globe very remote from each other, and which

* It is a very common mistake, especially in the United States, to consider *Negro* as synonymous with *African*. So far is this from being the fact, that, as Dr. Latham justly remarks, "the true Negro area, the area occupied by men of the black skin, thick lips, and woolly hair, is exceedingly small; as small in proportion to the rest of the continent, as the area of the district of the stunted Hyperboreans is in Asia, or that of the Lapps in Europe." ("Natural History of the Varieties of Man," p. 471.)

have no other mark of affinity whatever: whilst, on the other hand, it will often tend to separate races which every other character would lead us to bring together. It is to be remembered, moreover, that the varieties in the conformation of the skeleton, presented by the breeds of domesticated animals, are at least equal to those which are manifested in the conformation and colour of their soft parts; and we might reasonably expect, therefore, to meet with similar variations among the Human races. It is probable, however, that climate has not so much influence in producing such changes in the configuration of the body, as is exerted by the peculiar habits and mode of life of the different races; and Dr. Prichard has pointed out a very remarkable relation of this kind, in regard to the three principal types of form presented by the Skull.

1039. Among the rudest tribes of Men, hunters and savage inhabitants of forests, dependent for their supply of food on the accidental produce of the soil or on the chase,—among whom are the most degraded of the African nations, and the Australian savages,—a form of head is prevalent, which is most aptly distinguished by the term *prognathous*, indicating a prolongation or forward-extension of the jaws (Fig. 186). This character

Fig. 186.

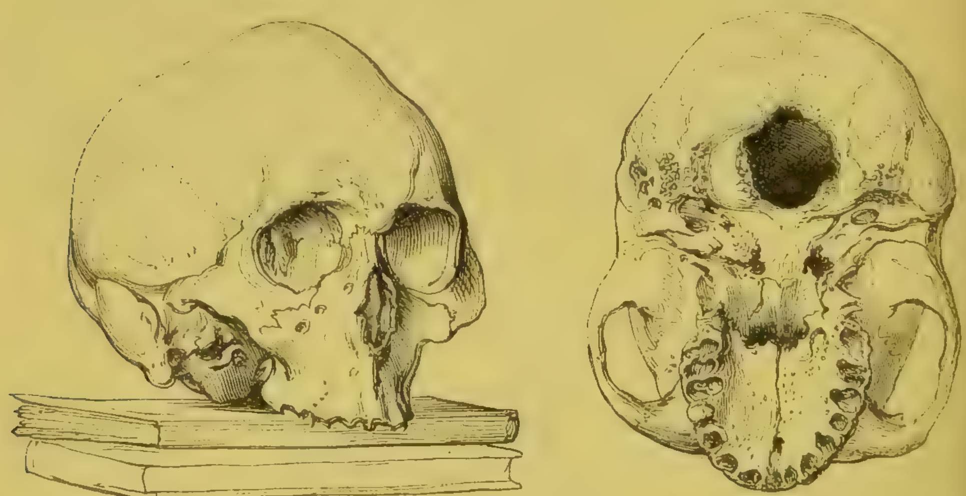
Profile and basal views of the *Prognathous Skull* of a Negro.

is most strongly marked in the Negroes of the Gold Coast, whose skulls ire usually so formed as to give the idea of lateral compression. The :emporal muscles have a great extent, rising high on the parietal bones; :he cheek-bones project forward, and not outward; the upper jaw is engthened and projects forwards, giving a similar projection to the ılveolar ridge and to the teeth; and the lower jaw has somewhat of the same oblique projection, so that the upper and lower incisor teeth are set ıt an obtuse angle to each other, instead of being nearly in parallel planes, ıs in the European. From the shape of the upper jaw alone, would result a marked diminution in the facial angle, measured according to the nethod of Camper; but this diminution is far from being sufficient to ıpproximate the Ethiopian races to the higher Apes, as some have supposed it to be (§ 8). Independently of the diminution of the facial ıngle, resulting from the projection of the upper jaw, it is quite certain

that, in the typical prognathous skull, there is a want of elevation of the forehead; but it does not appear that there is a corresponding diminution in the capacity of the cranial cavity, the retreating form of the forehead being partly due to the general elongation of the skull in the antero-posterior direction. Nor is it true, as stated by some, that the position of the foramen magnum in the Negro is decidedly behind that which it holds in the European, in this respect approaching that of the Apes (§ 2): since, if due allowance be made for the projection of the upper jaw, this aperture is found to have the same position in the prognathous skull as in the oval one, namely, exactly behind the transverse line bisecting the antero-posterior diameter of the base of the cranium. The prognathous skull is further remarkable for the large development of the parts connected with the organs of sense, especially those of smell and hearing. The aperture of the nostrils is very wide; and the internal space allowed for the expansion of the Schneiderian membrane, and for the distribution of the olfactory nerve, is much larger than in most European heads. The posterior openings of the nasal cavity are not less remarkable for their width, than the anterior. The external auditory meatus is also peculiarly wide and spacious; and the orbital cavities have been thought to be of more than ordinary capacity,—but this last is by no means a constant character.

1040. A second type of cranial conformation, very different from the preceding, belongs principally to the Nomadic races, who wander with their herds and flocks over vast plains; and to the tribes who creep along

Fig. 187.



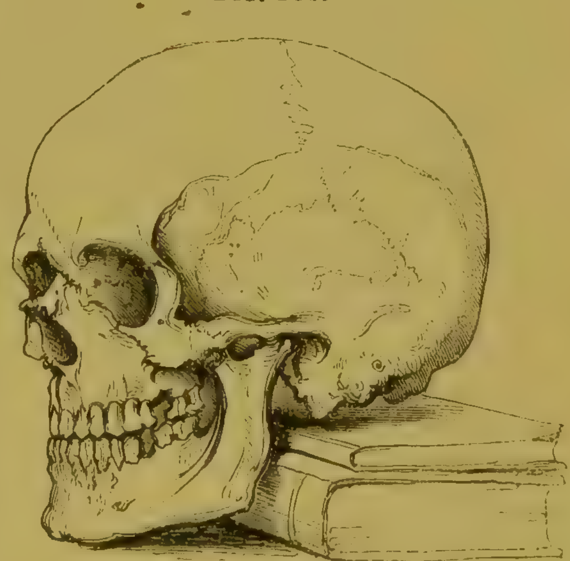
Front and basal views of the *Pyramidal Skull* of an Esquimaux.

the shores of the Icy Sea, and live partly by fishing, and in part on the flesh of their reindeer. This form, designated by Dr. Prichard as the *pyramidal*, is typically exhibited by various nations of Northern and Central Asia; and is seen, in an exaggerated degree, in the Esquimaux. Its most striking character is the lateral or outward projection of the zygoma, which is due to the form of the malar bones. These do not project forwards and downwards under the eyes, as in the prognathous skull; but take a direction laterally or outwards, forming, with the zygomatic

process of the temporal bone, a large rounded sweep or segment of a circle. From this, in connection with the narrowness of the forehead, it results, that lines drawn from the zygomatic arches, touching the temples on either side, instead of being parallel (as in Europeans), meet over the forehead, so as to form with the basis a triangular figure. The upper part of the face being remarkably flat, the nose also being flat, and the nasal bones, as well as the space between the eyebrows, being nearly on the same plane with the cheek-bones, the triangular space bounded by these lines may be compared to one of the faces of a pyramid. The orbits are large and deep; and the peculiar conformation of the bones which surround it, gives to the aperture of the lids an appearance of obliquity,—the inner angle seeming to be directed downwards. The whole face, instead of presenting an oval form, as in most Europeans and Africans, is of a lozenge-shape. The greater relative development of the zygomatic bones, and of the bones of the face altogether, when compared with the capacity of the cranium, indicates in the pyramidal skull a more ample extension of the organs subservient to sensation; the same effect being thus produced by lateral expansion, as by the forward extension of the facial bones in the prognathous skulls.

1041. The most civilized races,—those which live by agriculture and the arts of cultivated life,—all the most intellectually-improved nations of Europe and Asia,—have a shape of the head which differs from both the preceding forms, and which may be termed *oval* or *elliptical*. This at once approves itself as a more symmetrical form; no part having an excessive prominence; whilst, on the other hand, there is nowhere an appearance of undue flattening or compression. The head is altogether of a rounder shape than in other varieties, and the forehead is more expanded; while the maxillary bones and the zygomatic arches are so formed, as to give the face an oval shape, nearly on a plane with the forehead and cheek-bones, and not projecting towards the lower part. Owing to the more perpendicular direction of the alveolar processes, the front teeth are fixed in planes which are nearly or quite parallel to each other. The principal features in this form of cranium are thus of a negative character; the chief positive distinction is the large development of the cranial cavity, and especially the fulness and elevation of the forehead, in proportion to the size of the face;—indicating the predominance of the intellectual powers over those merely instinctive propensities, which are more directly connected with sensations. Among European nations, the Greeks have probably displayed the greatest symmetry and perfection in the form of the head; but various departures may be traced, towards the

FIG. 188.



*Oval Skull* of an European.

preceding forms, when we compare the crania of different races, and even of individuals, belonging to the same stock, — some approaching the pyramidal form of the Northern Asiatics, whilst others approximate to the prognathous type of the Negro.

1042. The influence of habits of life, continued from generation to generation, upon the form of the head, is remarkably evinced by the transition from one type to another, which may be observed in nations that have undergone a change in their manners and customs, and have made an advance in civilization. Thus, to mention but one instance, the Turks at present inhabiting the Ottoman and Persian empires, are undoubtedly descended from the same stock with the nomadic races, which are still spread through Central Asia (§ 1053). The former, however, having conquered the countries which they now inhabit, eight centuries since, have gradually settled-down to the fixed and regular habits of the Indo-European race, and have made corresponding advances in civilization; whilst the latter have continued their wandering mode of life, and can scarcely be said to have made any decided advance during the same interval. Now the long-since-civilized Turks have undergone a complete transformation into the likeness of Europeans; whilst their nomadic relatives retain the pyramidal configuration of the skull in a very marked degree. Some have attributed this change in the physical structure of the Turkish race, to the introduction of Circassian slaves into the harems of the Turks; but this could only affect the opulent and powerful amongst the race; and the great mass of the Turkish population have always intermarried among themselves. The difference of religion and manners must have kept them separate from those Greeks, whom they subdued in the new Ottoman countries; and in Persia, the Tajiks, or real Persians, still remain quite distinct from their Turkish rulers, belonging to a different sect among the Mussulmans, and commonly living apart from them.—In like manner, even the Negro head and face may become assimilated to the European, by long subjection to similar influences; thus, in some of our older West Indian Colonies, it is not uncommon to meet with Negroes, the descendants of those first introduced there, who exhibit a very European physiognomy; and it has even been asserted that a Negro belonging to the Dutch portion of Guiana may be distinguished from another belonging to the British settlements, by the similarity of the features and expression of each, to those which peculiarly characterize his masters. The effect could not be here produced by the intermixture of bloods, since this would be made apparent by alteration of colour.—But not only may the pyramidal and prognathous types be elevated towards the elliptical; the elliptical may be degraded towards either of these. Want, squalor, and ignorance, have a special tendency to induce that diminution of the cranial portion of the skull, and that increase of the facial, which characterize the prognathous type; as cannot but be observed by any one who takes an accurate and candid survey of the condition of the most degraded part of the population of the great towns of this country, but as is seen to be preeminently the case with regard to the lowest classes of Irish immigrants.* A certain degree of retrogression to the pyramidal type, is also to be noticed among the nomadic tribes which are to be found in every civilized com-

* See the "Dublin University Magazine," No. xlviii.

munity. Among these, as has been remarked by a very acute observer,* "According as they partake more or less of the purely vagabond nature, doing nothing whatsoever for their living, but moving from place to place, preying on the earnings of the more industrious portion of the community, so will the attributes of the nomade races be found, more or less marked in them; and they are all more or less distinguished for their high cheek-bones and protruding jaws;" thus showing that kind of mixture of the pyramidal with the prognathous type, which is to be seen among the lowest of the Indian and Malayo-Polynesian races.

1043. Next to the characters derived from the form of the head, those which are founded upon the form of the *pelvis* seem entitled to rank. These have been particularly examined by Professors Vrolik and Weber. The former was led by his examinations of this part of the skeleton, to consider that the pelvis of the Negress, and still more that of the female Hottentot, approximates to that of the Simiæ in its general configuration; especially in its length and narrowness, — the iliac bones having a more vertical position, so that the anterior spines approach one another much more closely than they do in the European; and the sacrum also being longer and narrower. On the other hand, Prof. Weber † concludes, from a more comprehensive survey, that no particular figure is a permanent characteristic of any one race. He groups the principal varieties which he has met with, according to the form of the upper opening, — whether oval, round, four-sided, or wedge-shaped. The first of these is most frequent in the European races; the second, among the American races; the third, most common among the Mongolian nations, corresponds remarkably with the form of their heads; whilst the last chiefly occurs among the races of Africa, and is in like manner conformable with the oblong compressed form usually presented by their cranium. But though there are particular shapes which are most prevalent in each race, yet there are numerous individual deviations, of such a nature that every variety of form presents itself occasionally in any given race.

1044. Other variations have been observed by anatomists, in the relative length of the bones, and in the shape of the limbs, between the different races of Man; but these also seem to have reference to the degree of civilization, and to the regularity of the supply of wholesome nutriment. It is generally to be observed that the races least improved by civilization, like the uncultivated breeds of animals, have slender, lean, and elongated limbs; this may be especially remarked in the natives of Australia. In nearly all the less civilized races of Men, the limbs are more crooked and badly formed than the average of those of Europeans; and this is particularly the case in the Negro, the bones of whose legs bow outwards, and whose feet are remarkably flat. It has been generally believed, that the length of the fore-arm in the Negro is so much greater than in the European, as to constitute a real character of approximation to the Apes. The difference, however, is in reality extremely slight; and is not at all comparable with that which exists between the most uncultivated races of Men and the highest Apes (§ 5). And in regard to all the peculiarities here alluded to, it is to be observed, that they can only be

* Mr. Henry Mayhew, in "London Labour and the London Poor," p. 2.

† "Die Lehre von den Ur- und Racenformen der Schaedel und Becken des Menschen;" Dusseldorf, 1830.

discovered by the comparison of large numbers of one race with corresponding numbers of another; for individuals are found in every tribe, possessing the characters which distinguish the majority of the other race. Such peculiarities, therefore, are totally useless as the foundation of *specific* characters; being simply variations from the ordinary type, resulting from causes which might affect the entire race, as well as individuals. — The connection between the general form of the body, on the one hand, and the degree of civilization (involving the regular supply of nutriment) on the other, is made apparent, not merely by the improvement which we perceive in the form, development, and vigour, of the frame, as we advance from the lowest to the most cultivated of the Human races; but also by the degradation that is occasionally to be met-with in particular groups of the higher tribes, which have been subjected for several generations to the influence of depressing causes. Of such degradation, occurring under circumstances that permit its successive steps to be traced, we have a remarkable example in the conversion of certain tribes of the Hottentot race into Bushmen (§ 1058); and there is very strong ground for the belief, that similar influences have operated at a more remote period, in the production of the peculiar characters of the Guinea-coast Negroes and Australian Bushmen.

1045. Independently, however, of the obvious modifying influence of external circumstances, much allowance must be made for that *tendency to variation*, which presents itself, more or less, in all those races of animals, which possess such a constitutional capability of adaptation to changes in climate, habits of life, &c., as enables them to live and flourish under a variety of conditions. Thus we find that the offspring of any one pair of domesticated animals do not all precisely agree among themselves, or with their parents, either in bodily conformation or in psychical character; but that *individual* differences, as they are termed, exist among them. Now, as this tendency to variation cannot be clearly traced to any influence of external circumstances, it is commonly distinguished by the term 'spontaneous;' but there is no effect without a cause; and as the widest differences of this kind present themselves in those races which are most obviously amenable to the influence of external conditions, we seem justified in attributing them to agencies operating unostensibly upon the parents, either previously to their intercourse, or at the time of coition (§ 975), or in the female during the period of utero-gestation (§ 1014). The difference between wild and domesticated animals in regard to *colour* affords a very good illustration of this general fact; for the uniformity among the former is no less remarkable than the want of constancy among the latter; and whilst variety of colour soon gives place to uniformity, when domesticated races return in any considerable degree towards their primitive state,* it very speedily developes itself in races which are undergoing the converse process.†—Now it is by taking

* This has been especially noticed in the horses, cattle, sheep, hogs, and dogs, introduced by the Spaniards into South America.

† Thus Mr. T. Bell informs us ("British Quadrupeds," 2nd edit., p. 203), that an Australian bitch, or dingo, in the Zoological Gardens, had a litter of puppies, the father of which was also of that breed; both parents had been taken in the wild state; both were of the uniform reddish-brown colour which belongs to the race, and the mother had never bred before; but the young, bred in confinement, and in a half domesticated state, were all more or less spotted.

advantage of those 'spontaneous' departures from the ordinary type, which present features of value to the breeders of domesticated animals, that *new races* are developed from time to time among these; any strongly-marked peculiarity which thus appears in only a single individual, being usually transmitted to some of its offspring, and being almost certainly perpetuated when *both* parents are distinguished by it, as happens when the products of the first procreation become capable of breeding with each other.*—Now there can be no hesitation in admitting, that the tendency to the so-called 'spontaneous' variation prevails in the Human race to a greater degree than in any other; since we find most remarkable diversities in features, complexion, hair, and general conformation, among the offspring of the same parentage; whilst more special modifications of the ordinary type, such as the possession of six fingers on each hand and of six toes on each foot, are of no unfrequent occurrence. Under ordinary circumstances, these modifications tend to disappear as often as they occur; the free intermixture of those members of the race which possess them, with those which depart less from the ordinary type, tending to merge them in the general average. But there can be no reasonable doubt that, if the same kind of segregation were practised among Mankind, which is adopted by the breeders of animals for the purpose of perpetuating a particular variety,—if, for example, the members of a six-fingered family were to intermarry exclusively with one another,—any such variety would be permanently established as a new race. Now if it be borne in mind, that the influence of a scanty population, in the early ages of the human race, by isolating different families from each other, and causing intermarriages among even the nearest relatives, would have been precisely the same with that which is now exercised by the breeders of animals, we see one reason why the varieties which *then* arose should have a much greater tendency to self-perpetuation, than those which *now* occasionally present themselves. And when, too, it is borne in mind, that the change in external conditions induced by migration, would thus operate not only upon the parents but upon the offspring, and would have a continual influence in so modifying the constitution of the latter, that the peculiarities thus acquired by them would be transmitted in yet greater intensity to their progeny, there is no real difficulty in accounting, upon the strictest physiological principles, for the widest departures from one common type of conformation, which we encounter in our survey of the different Races of Mankind.†

* See the history of the introduction of the *ancon* breed of sheep, characterized by a peculiar conformation of its limbs, in Massachusetts, given by Col. Hutchinson in the "Phil. Trans." for 1813. A very similar account has been recently given by Prof. Owen (in a Lecture delivered before the Society of Arts, Dec. 10, 1851), respecting the recent introduction of a new breed of merino sheep, distinguished for the long, smooth, straight, and silky character of the wool, and now known as the Mauchamp breed.—In both instances, the breed originated in the spontaneous appearance of a male lamb possessing the peculiarities in question; and from its offspring such a selection was made by the breeder, as enabled him to bring together males and females, both of which were distinguished by them.

† For a masterly digest of the analogical evidence furnished by the changes known to have been thus produced among domesticated animals, and of the modifications which particular tribes of Men can be shown to have undergone within the historic period, see Dr. Prichard's "Physical History of Mankind," and his "Natural History of Man;" see, also, the summary given by the Author in the "Cyclop. of Anat. and Physiol.," vol. iv. pp. 1301–1339.

1046. Hence we are led to conclude, that, so far as regards their Anatomical structure, there is no such difference among them as would justify to the Zoologist the assertion of their distinct origin. But further, it can be shown that although the comparison of the structural characters of the Human races does not furnish any positive evidence of their descent from a common stock, it proves that even if their stocks *were* originally distinct, there could have been no essential difference between them; the descendants of any one such stock being able to assume the characters of another. This, as already remarked, can be proved by historical evidence in regard to a sufficient number of tribes, to justify the same assertion with respect to others, whose languages, customs, habits of thought, &c. have an affinity strong enough to warrant us in regarding them as descendants of the same stock, whilst their physical conformation is widely different. Each principal geographical area, that is so isolated from others as to render it probable, *à priori,* that its population has extended from one centre,—such as the Continent of Africa or America,—contains races of very diversified physical characters, whose linguistic affinities make it almost certain that they must have had a common descent; and thus, in whatever mode the types of the principal varieties are selected, they are found to be connected by so gradual a series of intermediate or transitional forms, that it is impossible to draw any such line of demarcation between them, as would be required by a soundly-judging Naturalist for the boundary of distinct species.

1047. A very important confirmation of this view, is afforded by the essential agreement which exists among the different Races of Men in regard to their Physiological history; the variations which they present not being greater than those which we meet-with between the different individuals of any one race. Thus, we not only find the average duration of life to be the same (making allowance for circumstances which are likely to induce disease), but the various epochs of life,—such as the times of the first and second dentition, the period of puberty, the duration of pregnancy, the intervals of the catamenia, and the time of their final cessation,—present a marked general uniformity, such as does not exist among similar epochs in the lives of species that are nearly allied but yet unquestionably distinct. Further, the different races of Man are all subject to the same diseases, both sporadic, endemic, and epidemic; the only exceptions being those, in which the constitution of a race has *grown-to* a certain set of influences (as that of the Negro to the malaria which produce certain pernicious fevers in the European), producing an hereditary immunity in the race, which is capable of being acquired by individuals of other races, by a process of acclimatization commenced sufficiently early.*—The most important physiological test, however, of

* This view of the immunity of the Negro race from certain forms of Fever which are very fatal to Europeans, is justified, the Author believes, by all the facts known upon the subject. Much may be set down, as he is assured by Dr. Daniell, to the better adaptation of the Negro habits of life to their climate; and Europeans who exercise due caution (especially in regard to the functions of the skin), may preserve an immunity scarcely less complete. Dr. D. himself, having been taken prisoner by one of the Negro tribes at an early age, and having spent two years among them, seems to have been thoroughly acclimatized; and has subsequently passed many years on the most unhealthy parts of the

pecific unity or diversity, is that furnished by the Generative process. t may be considered as a fundamental fact, alike in the Vegetable and the Animal kingdom, that *hybrid* races, originating in the sexual conection of individuals of two different *species*, do not tend to self-perpetution; the hybrids being nearly sterile with each other, although they may ropagate with either of their parent-races, in which the hybrid race will on merge; whilst, on the other hand, if the parents be themselves *varie-es* of the same species, the hybrid constitutes but another variety, and s powers of reproduction are rather increased than diminished, so that may continue to propagate its own race, or may be used for the production of other varieties, almost *ad infinitum*. It appears that, among lants, hybrids originating between undoubtedly distinct species, sometimes reproduce themselves for two or three generations, but do not ontinue beyond the fourth. Amongst Animals, the limits of hybridity etween parents of distinct species are more narrow, since the hybrid totally unable to continue its race with one of its own kind;* and lthough it may propagate with one of its parent-species, the progeny will f course approach in character to the pure breed, and the race will peedily merge into it. In Animals, as among Plants, the mixed ffsprings, originating from different races within the limits of the same pecies, generally *exceed* in vigour, and in the tendency to multiply, the arent-races from which they are produced, so as to gain ground upon he older varieties, and gradually to supersede them. In this manner, y the *crossing* of the breeds of our domesticated animals, many new and uperior varieties have been produced. The general principle is, then, hat beings of distinct *species*, or descendants from stocks originally different, cannot produce a mixed race which shall possess the capability f perpetuating itself; whilst the union of *varieties* has a tendency to roduce a race, superior in energy and fertility to its parents. — The pplication of this principle to the Human races, leaves no doubt with spect to their specific unity; for, as is well known, not only do all the ces of Men breed freely with each other; but the mixed race is genelly superior in physical development, and in tendency to rapid multiication, to either of the parent-stocks; so that there is much reason to elieve that, in many countries, the mixed race between the Aborigines nd European colonizers will ultimately become the dominant power in he community. This is especially the case in India, South America, and olynesia.

1048. The question of *Psychical* conformity or difference among the aces of Mankind, is one which has a most direct bearing upon the queson of their specific unity or diversity; but it has an importance of its wn, even greater than that which it derives from this source. For, as

ast, without experiencing any severe attacks of illness, and in the enjoyment of very good neral health.—It is sometimes maintained that the Negro race possesses such a complete emption from the Yellow Fever of the United States, as marks its specific difference; ch, however, is not constantly the case, since Negroes occasionally suffer from it; and eir *comparative* immunity seems fairly attributable to the constitutional peculiarity *acquired* their African progenitors, and capable of being acquired by Europeans also.

* One or two instances have been stated to occur, in which a Mule has produced offspring om union with a similar animal; but this is certainly the extreme limit, since no one has er maintained that the race can be continued further than the second generation, without mixture with one of the parent-species.

has been recently argued with great justice and power,* the real Unity of Mankind does not lie in the consanguinity of a common descent, but has its basis in the participation of every race in the same moral nature, and in the community of moral rights which hence becomes the privilege of all. "This is a bond which every man feels more and more, the farther he advances in his intellectual and moral culture, and which in this development is continually placed upon higher and higher ground; so much so, that the physical relation arising from a common descent is finally lost sight of, in the consciousness of the higher moral obligations." It is in these obligations, that the moral *rights of men* have their foundation; and thus, "while Africans have the hearts and consciences of human beings, it could never be right to treat them as domestic cattle or as wild fowl, if it were ever so abundantly demonstrated that their race was but an improved species of ape, and ours a degenerate kind of god." —The Psychical comparison of the various Races of Mankind, is really, therefore, in a practical point of view, the most important part of the whole investigation; but it has been, nevertheless, the one most imperfectly pursued, until the inquiry was taken up by Dr. Prichard. The mass of evidence which he has accumulated on this subject, however, leaves no reasonable doubt that no more "impassable barrier" really exists between the different races with respect to this, than in regard to any of those points of ostensible diversity which have been already considered; the variations in the positive and relative development of their respective psychical powers and tendencies, not being greater, either in kind or degree, than those which present themselves between individuals of our own or of any other race, by some members of which a high intellectual and moral standard has been attained. The tests by which we recognise the claims of the outcast and degraded of our own or of any other 'highly-civilized' community, to a common humanity, are the same as those by which we should estimate the true relation of the Negro, the Bushman, or the Australian, to the cultivated European. If, on the one hand, we admit the influence of want, ignorance, and neglect, in accounting for the debasement of the savages of our own great cities,—and if we witness the same effects occurring under the same conditions among the Bushmen of Southern Africa (§ 1058),—we can scarcely hesitate in admitting, that the long-continued operation of the same agencies has had much to do with the psychical as well as the physical deterioration of the Negro, Australian, and other degraded savages. So, on the other hand, if we cherish the hope that the former, so far from being irreclaimable, may at least be brought-up to the standard from which they have degenerated, by means adapted to develope their intellectual faculties and to call-forth the higher parts of their moral nature, no adequate reason can be assigned why the same method should not succeed with the latter, if employed with sufficient perseverance. It will be only when the effect of education, intellectual, moral, and religious, shall have been fairly tested by the experience of *many generations*, in conjunction with the influence of a perfect equality in civilization and social position, that we shall be entitled to speak of any essential and constant psychical difference be-

* See the "New Quarterly Review," No. xv., p. 131; and an Article by Prof. Agassiz in the "Christian Examiner," Boston (N. E.), 1850.

een ourselves and the most degraded beings clothed in a human form. l the evidence which we at present possess, leads to the belief, that der a vast diversity in degree and in modes of manifestation, the same ellectual, moral, and religious *capabilities* exist in all the Races of ankind; so that, whilst we may derive from this conformity a powerful gument for their zoological Unity as a species, we are also directly led recognize their community of moral nature with ourselves, and to mit them to a participation in our own rights.

1049. Most important assistance is afforded in the determination of e real affinities of different Races, by the study of their *Languages.* is, however, is a department of the inquiry so far beyond the limits of ysiological science, that it must be here dismissed with a bare mention the results, to which the zealous pursuit of it by a large number of ilosophic philologists seems undoubtedly to tend.—There can be no asonable doubt that, as a general principle, the affinities of races are ore surely indicated by their languages, than by their physical features; d the experienced philologist is generally able to discriminate those semblances, which may have arisen out of the introduction of words or modes of construction from the one into the other, by conquest, com- ercial intercourse, or absolute intermixture, from those which are the sult of a community of origin. And thus are supplied those means of acing the past history of races, which are seldom afforded by historical cords, or even (at least with any degree of certainty) by traditional infor- ation. It is to be borne in mind, that the affinities of languages are licated, not merely by verbal resemblance, but by the similarity of eir modes of grammatical construction, or the methods by which the ation between different words that constitute sentences is indicated. e most positive evidence is of course afforded, when a conformity exists th in the *vocabularies* and in the *types of construction* of two lan- ages; but it frequently happens that although the conformity exists in gard to one of these alone, yet the evidence which it affords is per- tly satisfactory. Thus, there are many cases in which the vocabularies e so continually undergoing important changes (the want of written cords not permitting them to acquire more than a traditional perma- nce), that their divergence becomes so great, even in the course of a v generations, as to prevent tribes which are by no means remotely scended from a common ancestry, from understanding one another; ilst yet the system of grammatical construction, which depends more on the grade of mental development and upon habits of thought, hibits a remarkable permanence. Such appears to be true of the whole oup of American languages; which seem, as a whole, to be legitimately ferable to a common stock, notwithstanding their complete verbal versity. On the other hand, when two languages or groups of lan- ages differ greatly in construction, but present that kind of verbal cor- spondence on which the philologist feels justified in placing most iance (namely, an essential conformity in those 'primary words' which ve to represent the universal ideas of a people in the most simple state existence), that correspondence may be held to indicate a community origin, if it can be proved that it has not been the result of intercourse tween the two families of nations subsequently to their first divergence, d if it seems probable on other grounds that their separation took place

at a period when as yet the grammatical development of both languages was in its infancy. Such appears to have been the case with certain of those groups of languages, whose distinctness can be traced back historically for the longest period.—It is evident, then, that Philological inquiry must be looked-to as one of the chief means of determining the question of radiation from a *single* centre or from *multiple* centres; and it is a remarkable fact, that the linguistic affinity and the conformity in physical characters frequently stand in a sort of complemental relation to each other, each being the strongest where the other is weakest; so that, by one or other of these links of connection, a close relationship is indicated between all these families of nations, under which the several races appear to be most naturally grouped.

## 2. *General Survey of the Principal Families of Mankind.*

1050. The distribution of the Races of Mankind under five primary varieties, according to their respective types of cranial conformation, as first proposed by Blumenbach, is still so commonly received, notwithstanding the distinct proof which has been given of the fallacious nature of its basis, that it will be desirable to explain his terms, and at the same time to show how far the information subsequently acquired has tended to modify his arrangement.—The first of these varieties, which is considered to be distinguished by the possession of the *oval* or *elliptical* type of cranial conformation, was designated *Caucasian* by Blumenbach, on two grounds; first, because he considered the Caucasian people (Georgians and Circassians) as presenting its physical characters in the greatest perfection; and second, because it was supposed that the Caucasian range of mountains might be regarded as the centre or focus of the races belonging to it. Neither of these ideas, however, is correct: for whilst the oval form of cranium is presented with fully as great beauty and symmetry by the Greeks, it seems now to be almost certainly determinable by the evidence of language, that the Georgian and Circassian nations are really of Mongolian origin, and consequently have no direct relation of affinity with the other nations usually ranked as belonging to this variety; and the evidence of history and tradition, so far from pointing to the Caucasian range as the original centre of radiation of the race, accords with that of language in assigning its locality much nearer to Central Asia. It would be most desirable, therefore, that some other designation should be substituted for that given by Blumenbach; were it not that the present state of our knowledge requires the entire abandonment of his doctrine, that the races agreeing in this type of conformation are mutually connected by community of descent. For, even within the limits of Europe, we find at least two nations,—the Turks, and the Magyars or true Hungarians,—whose crania are characteristically oval, and which are yet undoubtedly of Mongolian descent; and although some allowance must be made, in regard to the change which has taken place among the former, for the influence of intermixture with other races, yet there is no reason to believe that any such influence has operated among the Magyars, whose blood seems to have been transmitted with remarkable purity from the time when they settled in Hungary about ten centuries since. In Asia, we find this type presented not merely by the Indo-European races, but

so by the Syro-Arabian, and by the larger proportion of the inhabitants ' Hindostan; yet the Syro-Arabian races are more nearly related to the frican stock (§ 1052), than to that from which most of the present habitants of Europe have sprung; and there is good reason to believe at the great mass, if not the whole, of the existing inhabitants of India, re of Mongolian descent (§ 1054). It will be necessary, therefore, to onsider the nations which present the so-called Caucasian type of cranial onformation, under several distinct heads. No uniformity exists among em in regard to *colour;* for this character presents every intermediate adation between the fair and florid hue, with light, red, or auburn hair, ' the Northern European, to the jet-black of many tribes in Northern frica and the Indian Peninsula. The hair is generally long and flexible, ith a tendency to curl; but considerable variety presents itself with gard to this particular. The conformation of the features approaches ore or less closely to that which we are accustomed to regard as the pe of beauty.

1051. The first place, in a more natural distribution of the Human Races, ust undoubtedly be given to that which is designated by Dr. Prichard the *Arian,* and which is often termed the *Indo-European;* including e collective body of European nations, with the Persians, Affghans, nd certain other nations of the south-western portion of the Asiatic ontinent, near to which their original focus appears to have been. The eat bond of connection between these nations, lies in their languages; hich, in spite of great diversities, present a certain community of aracter that is recognised by every philologist. The family which is ost dissimilar to the rest, is that which is formed by the Celtic nations; ese are undoubtedly, like the others, of Eastern origin, as was first shown Dr. Prichard;* but they appear to have detached themselves from e common stock at an earlier period in the development of its lanuage; and both in their physical conformation and in their psychical aracter, the typical Celt contrasts remarkably with the Germanic oup of nations. The languages of the whole Indo-Germanic group are ited alike by community in many of the most important 'primary ords,' and by general similarity in grammatical construction; being viously all formed upon the same base with the ancient Sanskrit, if not on the Sanskrit itself. The existing Lettish or Lithuanian dialect esents a very near approach to that type; and the Old Prussian, dialect spoken as late as the sixteenth century, had a still closer liance to the ancient Zend or Median, which seems to have been a very rly derivation from the Sanskrit, and which is the basis of the language w spoken in Persia. But there is evidence that, notwithstanding the utual affinities of the Indo-Germanic languages, every one of them has en modified by the introduction of extraneous elements: thus, in those ' Western Europe, there is a considerable admixture of Celtic; whilst others, there are traces of more barbaric tongues. In fact, there can little doubt that Europe had an indigenous population, before the migration of the Indo-German or even of the Celtic tribes; and of this pulation it seems most probable that the Lapps and Finns of Scandivia, and the Euskarians (or Basques) of the Biscayan provinces, are

* "On the Eastern Origin of the Celtic Nations," 1831.

but the remnant. The former of these tribes, which is undoubtedly of Mongolian origin, once extended much further south than at present; and with regard to the latter, whose nearest linguistic affinities are also with the tongues of High Asia, there is ample historical proof that they had formerly a very extensive distribution through Southern Europe. It would not seem improbable, then, that the advance of the Indo-European tribes from the south-east corner into central Europe, separated that portion of the aboriginal (Mongolian) population which they did not absorb or destroy, into two great divisions; of which one was gradually pressed northward and eastward, so as to be restricted to Finland and Lapland; and the other southward and westward, so as to be confined at the earliest historic period to a part of the peninsula of Spain and the south of France, gradually to be driven before the successive irruptions of the Celts, Romans, Arabians, and other nations, until their scanty remnant found an enduring refuge in the fastnesses of the Pyrenees.*—The Indo-Germanic race is unquestionably that which has exercised the greatest influence on the civilization of the Old World; and it seems indubitably destined to acquire a similar influence in those newly-found lands, which have been discovered by its enterprise. With scarcely an exception, as Dr. Latham has justly remarked, the nations belonging to it present an *encroaching* frontier: there being no instance of its permanent displacement by any other race, save in the case of the Arab dominion in Spain, which has long since ceased; in that of the Turkish dominion in Turkey and Asia Minor, which is evidently destined to expire at no distant period, being upheld for merely political purposes by extraneous influence; and in that of the Magyars in Hungary, who only maintain their ground through their complete assimilation to the Indo-Germanic character. It is a remarkable fact, that in most cases in which this race extends itself into countries previously tenanted by people of an entirely different type, the latter progressively decline and at last disappear before it, provided the climate be such as enables it to maintain a vigorous existence; this is pre-eminently the case in North and South America, in Australia, in New Zealand, and in many of the smaller Polynesian islands. And where the climate is less favourable to the perpetuation of the race in its purity, an intermixture with the native blood frequently gives rise to a mixed race, which possesses the developed intellect of the one, and the climatic adaptiveness of the other, and which appears likely ultimately to take the place of both.

1052. The *Syro-Arabian* or *Semitic* nations, agree with the preceding in general physical characters, but differ entirely in the structure of their language, and for the most part in vocabulary also, though recent researches seem to indicate that certain *roots* of the Semitic and Indo-Germanic languages have a decided affinity. It seems quite certain, however, that the linguistic affinities of the Semitic nations are rather with the *African* than with the Indo-European races; and so strong is the link of connection thus established, that by Dr. Latham they are ranked

* This view, which was suggested by the Author in the "Brit. and For. Med. Rev.," Oct. 1847, without the knowledge that it had been elsewhere propounded, has been put forth with considerable confidence by Dr. Latham ("Varieties of Man," 1850), as having originated with Arndt and been adopted by Rask, distinguished Scandinavian ethnologists.

with the former under the general designation *Atlantidæ*,* whilst Mr. Norris, whose authority upon all such subjects is deservedly great, is strongly disposed (as he has himself informed the Author) to consider them an *essentially African* people.—The original centre of this race, however, is commonly reputed to have been that region of Asia which is intermediate between the countries of the Indo-European and of the Egyptian races; having as its centre the region watered by the great rivers of Mesopotamia. Several of the nations originally constituting this group have become extinct, or nearly so; and the *Arabs*, which originally formed but one subdivision of it, have now become the dominant race, not only throughout the ancient domain of the Syro-Arabian nations, but also in Northern Africa. In the opinion of Baron Larrey, who had ample opportunities for observation, the skulls of the Arabian race furnish, at present, the most complete type of the human head; and he considered the remainder of the physical frame as equally distinguished by its superiority to that of other races of men. The different tribes of Arabs present very great diversities of colour, which are generally found to coincide with variations in climate. Thus the Shegya Arabs, and others living on the low countries bordering on the Nile, are of a dark-brown or even black hue; but even when quite jetty, they are distinguished from the Negro races by the brightness of their complexions, by the length and straightness of their hair, and by the regularity of their features. The same may be said of the wandering Arabs of Northern Africa; but the influence of climate and circumstances is still more strongly marked in some of the tribes long settled in that region, whose descent may be traced to a distinct branch of the Syro-Arabian stock, namely, the *Berber*, to which belong the Kabyles of Algiers and Tunis, the Tuaryks of Sahara, and the Guanches or ancient population of the Canary Isles. Amongst these tribes, whose affinity is indisputably traceable through their very remarkable language, every gradation may be seen, from the intense blackness of the Negro skin, to the more swarthy hue of the inhabitants of the South of Europe. It is remarkable that some of the Tuaryk inhabitants of particular Oases in the great desert, who are almost as insulated from communication with other races as are the inhabitants of islands in a wide ocean, have hair and features that approach those of the Negroes; although they speak the Berber language with such purity, as to forbid the idea of the introduction of these characters by an intermixture of races. The *Jews*, who are the only remnants now existing of the once powerful Phœnician tribe, and who are now dispersed through nearly every country on the face of the earth, present a similar diversity; having gradually assimilated in physical characters to the nations among which they have so long resided (§ 1035).

1053. The second primary division of the Human family, according to the arrangement of Blumenbach, is that commonly termed *Mongolian*. The real Mongols, however, constitute but a single and not very considerable member of the group of nations associated under this designation; which is, therefore, by no means an appropriate one. The original seat of these races appears to have been the great central elevated plain of Asia, in which all the great rivers of that continent have their sources, whatever

* See his "Varieties of Man," 1850, p. 469.

may be their subsequent direction. Taken as a whole, this division is characterized by the pyramidal form of the skull, whose antero-posterior diameter scarcely exceeds the parietal, and by the broad flat face and prominent cheek-bones; by the flattening of the nose, which is neither arched nor aquiline; by the eyes being drawn upwards at their outer angle; by the xanthous or olive complexion, which sometimes becomes fair, but frequently swarthy; by the scantiness and straightness of the hair, and by deficiency of beard; and by lowness of stature. These characters, however, are exhibited in a prominent degree only in the more typical members of the group; and may become so greatly modified as to cease altogether to be recognizable. Such a modification has been remarkably effected in the case of the *Turkish* people, now so extensively distributed. All the most learned writers on Asiatic history are agreed in opinion, that the Turkish races are of one common stock; although at present they vary in physical characters, to such a degree that, in some, the original type has been altogether changed. Those which still inhabit the ancient abodes of the race, and preserve their pastoral nomadic life, present the physiognomy and general characteristics which appear to have belonged to the original Turkomans; and these are decidedly referable to the so-called Mongolian type. Before the Mahommedan era, however, the Western Turks or Osmanlis had adopted more settled habits, and had made considerable progress in civilization; and their adoption of the religion of Islam incited them to still wider extension, and developed that spirit of conquest, which, during the middle ages, displayed itself with such remarkable vigour. The branches of the race, which, from their long settlement in Europe, have made the greatest progress in civilization, now exhibit in all essential particulars the physical characters of the European model; and these are particularly apparent in the conformation of the skull.—In like manner we find that the Ugrian division, which migrated towards the north-west at a very early period, planted a colony in Europe, which still tenants the northern Baltic countries, forming the races of *Finns* and *Lapps*. In the time of Tacitus, the Finns were as savage as the Lapps; but the former, during the succeeding ages, became so far civilized, as to exchange a nomadic life for one of agricultural pursuits, and have gradually assimilated with the surrounding people; whilst the Lapps, like the Siberian tribes of the same race, have ever since continued to be barbarous nomades, and have undergone no elevation in physical characters. The same division gave origin to the *Magyars* or Hungarians; a warlike and energetic people, unlike their kindred in the North; in whom a long abode in the centre of Europe has, in like manner, developed the more elevated characters, physical and mental, of the European nations.

1054. The nations inhabiting the South-eastern and Southern portion of Asia, also, appear to have had their origin in the Mongolian or Central Asiatic stock; although their features and form of skull by no means exhibit its characteristic marks, but present such departures from it, as are elsewhere observable in races that are making advances in civilization. The conformity to the Mongolian type is most decidedly shown by the nations (collectively termed *Seriform* by Dr. Latham), which inhabit China, Thibet, the Indo-Chinese peninsula, and the base of the Himalayan range; these are associated by certain linguistic peculiarities which

distinguish them from all other races; that primitive condition of human speech, in which there is a total absence of inflections indicative of the relation of the principal words to one another, being apparently preserved with less change in the tongues of these people, than in those of any other. The Chinese may be physically characterized as Mongolians softened down; and in passing from China towards India, through the Burmese empire, there is so gradual a transition towards the ordinary Hindoo type, that no definite line of demarcation can be anywhere drawn.—The inhabitants of the great peninsula of Hindostan have been commonly ranked (as already remarked) under the Caucasian race; both on account of their physical conformity to that type, and also because it has been considered that the basis of their languages is Sanskritic. It is certain, however, that this conclusion is incorrect with regard to a very large proportion of the existing population of India; and there is strong reason to believe that no part of it bears any real relation of affinity to the Indo-European group of nations, except such as may be derived from a slight intermixture. Thus, the *Tamulian*, which is the dominant language of *Southern* India, is undoubtedly not Sanskritic in its origin (although containing an infusion of Sanskritic words), but more closely approximates to the Seriform type; and many of the hill tribes, in different parts of India, speak peculiar dialects, which, though mutually unintelligible, appear referable to the same stock. Now it is among this portion of the population of India, that the greatest departure presents itself from the Caucasian type of cranial conformation, and the closest conformity to the Mongolian; the cheek-bones being more prominent, the hair coarse, scanty, and straight, and the nose flattened; sometimes, also, the lips are very thick, and the jaws project, showing an approximation to the prognathous type. Now in the opinion of Dr. Latham and Mr. Norris, the various dialects of *Northern* India (of which the *Hindostani* is the most extensively spoken) are to be regarded as belonging, in virtue of their fundamental nature, to the same group with those of High Asia, notwithstanding the large infusion of Sanskritic words which they contain; this infusion having been introduced at an early period by an invading branch of the Arian stock, of whose advent there is historical evidence, and whose descendants the ordinary Hindoo population have been supposed to be. According to this view, then, the influence of the Arian invasion upon the language and population of Northern India, was very much akin to that of the Norman invasion upon those of England; the number of individuals of the invading race being so small in proportion to that of the indigenous population, as to be speedily merged in it, not, however, without contributing to an elevation of its physical characters; and a large number of new words having been in like manner introduced, without any essential change in the type of the original language. And thus the only distinct traces of the Arian stock are to be found in the Brahminical caste, which preserves (though with great corruption) the original Brahminical religion, and which keeps up the Sanskrit as its classical language; it is certain, however, that this race is far from being of pure descent, having intermingled to a considerable extent with the ordinary Hindoo population. There is but little to remind us of the Mongolian type in the countenances of the Hindoos, which are often remarkable for a symmetrical beauty that only wants a

more intellectual expression to render them extremely striking; some traces of it, however, may perhaps be found in the rather prominent zygomatic arches which are common amongst them; but the cranial portion of the skull presents no approach to the pyramidal type, being often very regularly elliptical. There is a remarkable difference in the colour of the different Hindoo tribes; some being nearly as dark as Negroes, others more of a copper colour, others but little darker than the inhabitants of Southern Europe, whilst others who can be shown to have migrated at a remote period into one of the hilly districts of Northern India, have a fair complexion with blue eyes and auburn or even red hair.—Another marked departure from the ordinary Mongolian type is presented by the Hyperborean tribes inhabiting the borders of the Icy Sea; these have for the most part a pyramidal skull, but their complexion is swarthy and their growth is peculiarly stunted; and they form the link that connects ordinary Mongolidæ with the Lapps and Finns of Europe on one side, and with the Esquimaux of North America on the other.

1055. According to the usual mode of dividing the Human family, the *Ethiopian* or *Negro* stock is made to include all the nations of Africa, to the southward of the Atlas range. But, on the one hand, there is good reason for separating the Hottentots and Bushmen of the southern extremity as a distinct race; so, again, the region north of the Great Desert is mostly occupied by *Semitic* tribes; the scattered population of the Great Desert itself is far from being Negro in many of its features; the valley of the Nile, at least in its middle and lower portions, including Egypt, Nubia, and even Abyssinia, is inhabited by a group of nations which may be designated as Nilotic, and which presents a series of gradational transitions between the Negroes and Kaffres and the Semitic races; a large portion of the area south of the Equator is occupied by the Kaffre tribes and their allies, which cannot be truly designated as Negroes; so that the true Negro area is limited to the western portion of the African continent, including the alluvial valleys of the Senegal, the Gambia, and the Niger, with a narrow strip of central Africa, passing eastwards to the alluvial regions of the Upper Nile. Even within this area, the true Negro type of conformation, such as we see in the races which inhabit the low countries near the Slave Coast,—consisting in the combination of the prognathous form of skull with receding forehead and depressed nose, thick lips, black woolly hair, jet-black unctuous skin, and crooked legs,—is by no means universally prevalent; for many of the nations which inhabit it, must be ranked as *sub-typical* Negroes; and from these the gradation in physical characters is by no means abrupt, to those African nations which possess, in a considerable degree, the attributes which we are accustomed to exclude altogether from our idea of the African race. Thus, the race of Jolofs near the Senegal, and the Guber in the interior of Sudan, have woolly hair and deep black complexions, but fine forms and regular features of a European cast; and nearly the same may be said of the darkest of the Kaffres of Southern Africa. The Bechuana Kaffres present a still nearer approach to the European type; the complexion being of a light brown, the hair often not woolly but merely curled, or even in long flowing ringlets, and the figure and features having much of the European character.—There is no group, in fact, which pre-

sents a more constant correspondence between external conditions and physical conformation, than that composed of the African nations. As we find the complexion becoming gradually darker, in passing from northern to southern Europe, thence to North Africa, thence to the borders of the Great Desert, and thence to the intertropical region where alone the dullest black is to be met with,—so do we find, on passing southwards from this, that the hue becomes gradually lighter in proportion as we proceed further from the equator, until we meet with races of comparatively fair complexions among the nations of Southern Africa. Even in the intertropical region, high elevations of the surface have the same effect as we have seen them to produce elsewhere, in lightening the complexion. Thus the high parts of Senegambia, where the temperature is moderate and even cool at times, are inhabited by Fulahs of a light copper colour, whilst the nations inhabiting the lower regions around them are of true Negro blackness: and nearly on the same parallel, but at the opposite side of Africa, are the high plains of Enarea and Kaffa, where the inhabitants are said to be fairer than the natives of Southern Europe.

1056. The languages of the Negro nations, so far as they are known, seem to belong to one group; for although there is a considerable diversity in their vocabularies (arising in great part from the want of written records which would give fixity to their tongues), yet they seem to present the same grade of development and the same grammatical forms; and various proofs of their affinity with the Semitic languages have been developed, these being afforded by similarity alike of roots and of grammatical construction. The Semitic affinity of the Negro nations is further indicated in a very remarkable manner, by the existence of a variety of superstitions and usages among the Negroes of the Western coast, closely resembling those which prevail also among the Nilotic races whose Semitic relations are most clear, as well as among branches of the Semitic stock itself; and thus we seem to have adequate proof of the absence of any definite line of demarcation, in regard either to *physiological* or to *linguistic* characters, between the Negro race, and one of those which has always been considered to rank as among the most elevated forms of the Caucasian variety.—Nor is there anything in the *psychical* character of the Negro, which gives us a right to separate him from other races of Mankind. It is true that those races which have the Negro character in an exaggerated degree, are uniformly in the lowest stage of society, being either ferocious savages, or stupid, sensual, and indolent; such are most of the tribes along the Slave Coast. But, on the other hand, there are many Negro states, the inhabitants of which have attained a considerable degree of improvement in their social condition; such are the Ashanti, the Sulima, and the Dahomans of Western Africa, also the Guber of Central Sudan, among which a considerable degree of civilization has long existed; the physical characters of all these nations deviate considerably from the strongly-marked or exaggerated type of the Negro; and the last are perhaps the finest race of genuine Negroes on the whole continent, and present in their language the most distinct traces of original relationship to the Syro-Arabian nations. The highest civilization, and the greatest improvement in physical characters, are to be found in those African nations which have adopted the Mohammedan religion;

this was introduced, three or four centuries since, into the eastern portion of Central Africa; and it appears that the same people, which were then existing in the savage condition still exhibited by the pagan nations further south, have now adopted many of the arts and institutions of civilized society, subjecting themselves to governments, practising agriculture, and dwelling in towns of considerable extent, many of which contain 10,000, and some even 30,000 inhabitants; a circumstance which implies a considerable advancement in industry, and in the resources of subsistence. This last fact affords most striking evidence of the *improvability* of the Negro races; and, taken in connection with the many instances that have presented themselves, of the advance of individuals, under favourable circumstances, to at least the average degree of mental development among the European nations, it affords clear proof that the line of demarcation, which has been supposed to separate them intellectually and morally from the races that have attained the greatest elevation, has no more *real* existence than that which has been supposed to be justified by a difference in physical characters, and of which the fallacy has been previously demonstrated.

1057. The southern portion of the African continent is inhabited by a group of nations, which, as already mentioned, recede, more or less decidedly, from the Negro type in physical characters, and which seem connected together by essential community of language, as branches of the stock of which the Kaffres may be considered the stem. In this warlike nomadic people, which inhabit the eastern parts of South Africa, to the northward of the Hottentot country, so great a departure from the ordinary Negro type presents itself, that many travellers have assigned to them a different origin. The degree of this departure, however, varies greatly in the different Kaffre tribes; for whilst some of them are black, woolly-headed, and decidedly prognathous, so as obviously to approach the modified Negroes of Congo in general aspect, others recede considerably from the typical prognathous races, both in complexion, features, and form of head, presenting a light-brown colour, high forehead, prominent nose, and a tall, robust, well-shaped figure. The thick lips and black frizzled hair are generally retained, however; but the hair is sometimes of a reddish colour, and becomes flowing; and the features may present a European cast. Even among the tribes which depart most widely from the Negro type, however, individuals are found who present a return to it; and it is interesting to remark, that the people of Delagoa Bay, though of the Kaffre race (as indicated by their language), having been degraded by subjugation, approach the people of the Guinea Coast in their physical characters. In fact, between the most elevated Kaffre and the most degraded Negro, every possible gradation of physical and psychical characters is presented to us, as we pass northwards and westwards from Kaffraria towards the Guinea Coast; and we meet with a similar transition, although not carried to so great an extent, as we pass up the eastern coast.—The languages of the Kaffres and other allied tribes are distinguished by a set of remarkable characters, which have been considered as isolating them from other African tongues. According to Dr. Latham, however, these peculiarities are not so far without precedent elsewhere, as to establish the very decided line of demarcation which some have attempted to draw; and may be regarded, in fact, as

resulting from the fuller development of tendencies which manifest themselves in other African languages.

1058. The *Bushmen* or *Bosjesmen* of South Africa are generally regarded as presenting the most degraded and miserable condition of which the human race is capable; and they have been supposed to present resemblances in physical characters to the higher Quadrumana. Yet there is distinct evidence, that this degraded race is but a branch or subdivision of the once extensive nation of Hottentots; and that its present condition is in great part due to the hardships to which it has been subjected, partly in consequence of European colonization. The *Hottentot* race differs from all other South African nations, both in language and in physical conformation. The language cannot be shown to possess distinct affinities with any other stock;* but in bodily structure there is a remarkable admixture of the characters of the Mongolian with those of the Negro. Thus the face presents the very wide and high cheek-bones, with the oblique eyes and flat nose, of the Northern Asiatics; at the same time that, in the somewhat prominent muzzle and thick lips, it resembles the countenance of the Negro. The complexion is of a tawny buff or fawn colour, like the black of the Negroes diluted with the olive of the Mongols. The hair is woolly, like that of the Negroes, but it grows in small tufts scattered over the surface of the scalp (like a scrubbing-brush), instead of covering it uniformly; thus resembling in its comparative scantiness that of the Northern Asiatics. It is most interesting to observe this remarkable resemblance in physical characters, between the Hottentots and the Mongolian races, in connexion with the similarity that exists between the circumstances under which they respectively live; and it is not a little curious that the Hottentot, as the Mongol, should be distinguished by the extraordinary acuteness of his vision. No two countries can be more similar, than the vast steppes of Central Asia, and the karroos of Southern Africa; and the proper inhabitants of each are nomadic races, wandering through deserts remarkable for the wide expansion of their surface, their scanty herbage, and the dryness of their atmosphere, and feeding upon the milk and flesh of their horses and cattle. Of the original pastoral Hottentots, however, very few now remain. They have been gradually driven, by the encroachments of European colonists and by internal wars with each other, to seek refuge among the inaccessible rocks and deserts of the interior; and they have thus been converted from a mild, unenterprising race of shepherds, into wandering hordes of fierce, suspicious, and vindictive savages, treated as wild beasts by their fellow-men, until they become really assimilated to wild beasts in their habits and dispositions. This transformation has taken place, under the observation of

* It is considered by some, that the Hottentot language is a degraded Kaffre, as the Bushman language is a degraded Hottentot; but the Author is informed by Mr. Norris, that he sees no valid ground for this assumption, the affinities of the Hottentot language being rather, in his opinion, with the languages of High Asia, although the connecting links are extremely slight. Such as they are, however, they tend to confirm an idea suggested to the Author, some years since, by the marked reproduction of so many Mongolian characters in the Hottentot race, — that it is the remnant of a migration from Asia, earlier than that in which the great bulk of the African nations have their origin; and that it has been driven down to the remotest corner of the continent, just as the aboriginal (Mongolian) population of south-western Europe seems to have been driven back by the Indo-European immigration (§ 1050).

eye-witnesses, in the Koranas, a tribe of Hottentots well known to have been previously the most advanced in all the improvements which belong to pastoral life; for having been plundered by their neighbours, and driven out into the wilderness to subsist upon wild fruits, they have adopted the habits of the Bushmen, and have become assimilated in every essential particular to that miserable tribe.—It appears, however, from the inquiries of Dr. Andrew Smith, that this process of degradation has been in operation quite independently of external agencies; nearly all the South African tribes who have made any advances in civilization, being surrounded by more barbarous hordes, whose abodes are in the wildernesses of mountains and forests, and who constantly recruit their numbers by such fugitives as crime and destitution may have driven from their own more honest and more thriving communities; and these people vary their mode of speech designedly, and even adopt new words, in order to make their meaning unintelligible to all but the members of their own community. All this has its complete parallel in the very midst of our own or any other highly civilized community; all our large towns containing spots nearly as inaccessible to those unacquainted with them, as are the rude caves or clefts of hills, or the burrows scooped out of the level karroo, in which the wretched Bushman lies in wait for his prey; and these being tenanted by a people that have been well characterized as *les classes dangereuses*, which, as often as the arm of the law is paralysed, issue forth from the unknown deserts within which they lurk, and rival in their fierce indulgence of the most degrading passions, and in their excesses of wanton cruelty, the most terrible exhibitions of barbarian inhumanity. Such outcasts, in all nations, purposely adopt, like the Bushmen, a 'flash' language; and in their general character and usages, there is a most striking parallel.*

1059. The *American* nations, taken collectively, form a group which appears to have existed as a separate family of nations from a very early period in the world's history. They do not form, however, so distinct a variety, in regard to physical characters, as some anatomists have endeavoured to prove; for, although certain peculiarities have been stated to exist in the skulls of the aboriginal Americans, yet it is found, on a more extensive examination, that these peculiarities are very limited in their extent,—the several nations spread over this vast continent differing from each other in physical peculiarities, as much as they do from those of the Old World, so that no typical form can be made-out among them. In regard to complexion, again, it may be remarked, that although the native Americans have been commonly characterized as "red men," they are by no means invariably of a red or coppery hue, some being as fair as many European nations, others being yellow or brown, and others nearly, if not quite, as black as the Negroes of Africa; whilst, on the other hand, there are tribes equally red, and perhaps more deserving that epithet, in Africa and Polynesia.—In spite of all this diversity of conformation, it is believed that the structure of their languages affords a decided and clearly-marked evidence of relationship between them. The words, and even the roots, may differ entirely in the different groups of American nations; but there is a remarkable similarity in grammatical construction amongst them all,

* See "London Labour and the London Poor," p. 2.

which is of a kind not only to demonstrate their mutual affinity, but to separate them completely from all known languages of the old continent. Notwithstanding their diversities in mode of life, too, there are peculiarities of mental character, as well as a number of ideas and customs derived from tradition, which seem to be common to them all, and which for the most part indicate a former elevation in the scale of civilization, that has left its traces among them even in their present degraded condition, and that still distinguishes them from the sensual, volatile, and almost animalized savages, that are to be met with in many parts of the Old Continent. — The Esquimaux constitute an exception to all general accounts of the physical characters of the American nations; for in the configuration of their skulls, as also in their complexion, and general physiognomy, they conform to the Mongolian type, even presenting it in an exaggerated degree. Their wide extension along the whole northern coast of America, and the near proximity of this coast to Kamschatka, certainly lend weight to the idea that they derive their origin from the Northern Asiatic stock; but, on the other hand, they have a marked affinity, in regard to language, to the other American nations. The Athapascan Indians, various tribes of which inhabit the country south of the Esquimaux country, seem intermediate in physical characters, as they are in geographical position, between the Esquimaux and the ordinary Americans. They have a tradition which seems to indicate that they are derived from the North-Eastern Asiatics, with whom they have many points of accordance in dress and manners.

1060. It now remains for us to notice the *Oceanic* races, which inhabit the vast series of islands scattered through the great ocean that stretches from Madagascar to Easter Island. There is no part of the world, which affords a greater variety of local conditions than this, or which more evidently exhibits the effects of physical agencies on the organization of the human body. Moreover, it affords a case for the recognition of affinities by means of language, that possesses unusual stability; since the insulated position of the various tribes that people the remote spots of this extensive tract, prevents them from exercising that influence upon each other's forms of speech, which is to be observed in the case of nations united by local proximity or by frequent intercourse. Tried by this test, it is found that the different groups of people inhabiting the greater part of these insular tracts, are more nearly connected together, although so widely scattered and so diverse in physical characters, than most of the families of men occupying continuous tracts of land on the great continents of the globe. The inhabitants of Oceania seem divisible into two principal groups, which are probably to be regarded as having constituted distinct races from a very early period; these are the Malayo-Polynesian race, and the Pelagian Negroes or Negritos.

1061. The *Malayo-Polynesian* group is by far the more extensive of the two; and comprehends the inhabitants of the greater part of the Indian and Polynesian Archipelagoes, with the peninsula of Malacca (which is the centre of the Malays proper), and perhaps the inhabitants of Madagascar. These are all closely united by affinities of language. The proper Malays bear a strong general resemblance to the Mongolian races, and this resemblance is shared, in a greater or less degree, by most of the inhabitants of the Indian Archipelago. They are of a darker complexion,

as might be expected from their proximity to the equator; but in this complexion, yellow is still a large ingredient. The Polynesian branch of the group presents a much wider diversity; and if it were not for the community of language, it might be thought to consist of several races, as distinct from each other as from the Malayan branch. Thus the Tahitians and Marquesans are tall and well-made; their figures combine grace and vigour; their skulls are usually remarkably symmetrical; and their physiognomy presents much of the European cast, with a very slight admixture of the features of the Negro. The complexion, especially in the females of the higher classes, who are sheltered from the wind and sun, is of a clear olive or brunette, such as is common among the natives of Central and Southern Europe; and the hair, though generally black, is sometimes brown or auburn, or even red or flaxen. Among other tribes, as the New Zealanders, and the Tonga and Friendly Islanders, there are greater diversities of conformation and hue; some being finely proportioned and vigorous, others comparatively small and feeble; some being of a copper-brown colour, others nearly black, others olive, and others almost white. In fact, if we once admit a strongly-marked difference in complexion, features, hair, and general configuration, as establishing a claim to original distinctness of origin, we must admit the application of this hypothesis to almost every group of islands in the Pacific;—an idea, of which the essential community of language seems to afford a sufficient refutation. Among the inhabitants of Madagascar, too, all of which speak dialects of the same language, some bear a strong resemblance to the Malayan type, whilst others present approaches to that of the Negro.

1062. The *Pelagian-Negro* races must be regarded as a group altogether distinct from the preceding; having a marked diversity of language; and presenting, more decidedly than any of the Malayo-Polynesians, the characters of the Negro type. They form the predominating population of New Britain, New Ireland, the Louisiade and Solomon Isles, of several of the New Hebrides, and of New Caledonia; and they seem to extend westwards into the mountainous interior of the Malayan Peninsula, and into the Andaman Islands in the Bay of Bengal. The Tasmanians, or aborigines of Van Dieman's Land, which are now almost complely exterminated, undoubtedly belonged to this group. Very little is known of them, except through the reports of the people of Malayo-Polynesian race inhabiting the same islands; but it appears that, generally speaking, they have a very inferior physical development, and lead a savage and degraded life. There is considerable diversity of physical characters among them; some approximating closely in hair, complexion, and features, to the Guinea-Coast Negroes; whilst others are of yellower tint, straight hair, and better general development. The *Papuans*, who inhabit the northern coast of New-Guinea and some adjacent islands, and who are remarkable for their large bushy masses of half-woolly hair, have been supposed to constitute a distinct race; but there is little doubt that they are of hybrid descent, between the Malays and the Pelagian Negroes.—To this group we are probably to refer the *Alfourous*, or *Alforian* race, which are considered by some to be the earliest inhabitants of the greater part of the Malayan Archipelago, and to have been supplanted by the more powerful people of the preceding races, who have

ier extirpated them altogether, or have driven them from the coasts o the mountainous and desert parts of the interior. They are yet to found in the central parts of the Moluccas and Philippines; and they m to occupy most of the interior and southern portion of New Guinea, ere they are termed Endamenes. They are of very dark complexion; t their hair, though black and thick, is lank. They have a peculiarly ulsive physiognomy; the nose is flattened, so as to give the nostrils an nost transverse position; the cheek-bones project; the eyes are large, e teeth prominent, the lips thick, and the mouth wide. The limbs are ng, slender, and misshapen. From the close resemblance in physical aracters between the Endamenes of New Guinea and the aborigines New Holland, and from the proximity between the adjacent coasts of ese two islands, it may be surmised that the latter belong to the Alrian race; but too little is known of the language of either, to give this ference a sufficient stability. In the degradation of their condition and anner of life, the savages of New Holland fully equal the Bushmen of outh Africa; and it is scarcely possible to imagine human beings, existng in a condition more nearly resembling that of brutes. But there is eason to believe, that the tribes in closest contact with European ettlers are more miserable and savage than those of the interior; and ven with respect to these, increasing acquaintance with their language, nd a consequent improved insight into their modes of thought, tend to aise the very low estimate which had been formed and long maintained, n regard to their extreme mental degradation. The latest and most uthentic statements enable us to recognize among them the same rinciples of a moral and intellectual nature, which, in more cultivated ribes, constitute the highest endowments of humanity; and thus to show hat they are not separated by any impassable barrier, from the most ivilized and elevated nations of the globe. — There are many indications, indeed, that the Negrito race is not so radically distinct from the Malayo-Polynesian, as the marked physical dissimilarity of their respective types, and the apparent want of conformity between their languages, would make it appear. For as, on the one hand, some of the subdivisions of the latter present a decided tendency towards that prognathous character and depth of complexion which are typical of the former, so among the former do we not unfrequently meet with a lighter shade of skin, a greater symmetry of skull, and a considerable improvement in form and feature. And although no very close relationship can be discovered between the Negrito and Malayo-Polynesian languages, yet it has been pointed-out by Mr. Norris that a much more decided relationship exists between the Australian and Tamulian (§ 1054); and remote as this connection seems, the circumstance adds weight to the idea, that the native Australians (with other Negrito tribes) are an offset from that southern branch of the great nomadic stock of Central Asia, which seems early to have spread itself through the Indo-Chinese and the Indian Peninsulas, and to have even there shown an approximation to the prognathous type.

1063. Looking, then, to the great diversity which exists among the subordinate groups of which both these divisions consist, and their tendency to mutual approximation, it cannot be shown that any sufficient reason exists for isolating them from each other; and, as already re-

marked, there seems no medium between the supposition that each island had its aboriginal pair or pairs, and the doctrine that the whole of Oceania has been peopled from a common stock. Looking, again, to the very marked approximation which is presented by certain Oceanic tribes to the Mongolian type, and this in a locality which, on other grounds, might be regarded as having received the first stream of migration, the possibility, to say the least, can scarcely be denied, that the main-land furnished the original stock, which has undergone various transformations subsequently to its first dispersion; these having been the result of climatic influence and mode of life, and having been chiefly influenced as to degree, by the length of time during which the transforming causes have been in operation. At any rate it may be safely affirmed, that there is no physical peculiarity which entitles the Oceanic races to rank as a group, which must have necessarily had an original stock distinct from that of the Continental nations.

## CHAPTER XXI.

### OF DEATH.

1064. It seems inherent in the very nature of Vital Action, that it can only be sustained during a *limited period* by any Organized body; for although the duration of certain structures may be prolonged, and their vital properties retained, almost indefinitely, yet this is only when the withdrawal of all extraneous agencies has reduced them to a condition of complete inactivity (§ 114). The Organized fabric, in fact, is at the same time the *instrument* whereby Vital Force is exercised, and the *subject* of its operation; and of this operation, as we have seen (§ 114), *decline* is no less a constituent part than *development*, and *Death* is its necessary sequence. Hence, in the performance of each one of those Functions whose aggregate makes up the Life of Man, the particular organ which ministers to that function undergoes a certain loss by the decline and death of its component tissues; and this the more rapidly, in proportion to the activity of the changes which are effected by their instrumentality. But if the regenerative processes be also performed with due vigour, no deterioration of the organ is manifested, since every loss of substance is compensated by the production of an equivalent amount of new and similar tissue. This regenerative power, however, gradually diminishes with the advance of years; and thus it happens that the entire organism progressively deteriorates (§ 133), and that Death at last supervenes from a general failure of the vital powers, rather than from the perversion or cessation of any one class of actions in particular.

1065. But Death may occur at any period of Life, from some local interruption produced by disease or injury in the regular sequence of vital actions; such interruption extending itself from the part in which it commences, to the organism in general, in virtue of that intimate mutual dependence of one function upon another, which is characteristic of all the higher orders of living beings. The death of the body as a whole,

ch may be appropriately designated *Somatic** death, becomes a neces-
y consequence of the death of a certain part of it, or *Molecular* death,
y when the cessation of activity in the latter interferes with the elabora-
, the circulation, or the depuration of the Blood, which supplies not
rely the nutritive *pabulum* to every part of the organism, but also the
gen which is essential to the activity of the nervo-muscular apparatus.
us, even in the higher animals, the death or removal of the limbs,
hough they may constitute (as in Man) a large proportion of the
ric, is not necessarily fatal; because it involves no interruption, either
the nutritive operations of the viscera, or in the sensorial functions of
brain.† On the other hand, the destruction of a certain minute
rtion of the nervous centres, or such a lesion of the heart's structure
would be trivial in almost any other organ, may be the occasion of
mediate death; because these changes arrest the respiratory move-
nts, or interfere directly with the action of the heart, so as to bring
flow of blood to a stand. It sometimes happens, however, that life
y be prolonged after the death or removal of some important organ,
consequence of the power which some other possesses of discharging its
action; thus we find that, in Man, the kidneys seem occasionally to
ke upon themselves the elimination of the constituents of bile from the
ood (§ 622); and in the Frog, the skin can perform part of the office
the lungs, so as to effect the aeration of the blood in a sufficient
gree to prolong life for some time, unless the temperature be elevated.‡
But although the vital activity of every part of the body is dependent
on a due supply of circulating fluid, yet this dependence is usually not
close as to involve the *immediate* suspension of vital activity in every
rt, whenever the general Circulation shall have been brought to a
nd. For we have distinct evidence of the persistence of vital changes
various organs and tissues of the body, after the death of the body at
rge; as is manifested in the performance of ciliary and of muscular
ovements (§§ 231, 328), in acts of secretion (§ 945) and perhaps even
nutrition, in the maintenance of the local circulation (§ 522), and in
e generation of animal heat (§ 652); and the fact is even yet more
markably manifested in the reunion (even after the lapse of some hours)
parts that have been entirely severed, such as fingers or toes, noses or
rs, by adhesion between the cut surfaces when brought into appo-
tion, which could not take place if the severed part were dead.

1066. The permanent and complete cessation of the Circulating current,
hich essentially constitutes *Somatic* Death, may be directly or indirectly
nsequent upon several distinct causes. — In the *first* place, it may be

* This term was first suggested by Dr. Prichard, in place of the less accurate term
ystemic' which was previously in use. (See "Cyclop. of Anat. and Physiol.," vol. i., p. 791.)

† The Author has been informed by Dr. Daniell, that it is not at all uncommon, in Negroes
ho are in the last stage of the adynamic fevers of the African coast, for death and decompo-
tion to extend gradually upwards from the extremities to the trunk; so that the former
ay be a state of absolute putrescence, before the respiration and circulation have been
rought to a stand; and he learns from his friend Prof. Jackson of Philadelphia, that he has
ore than once witnessed the same occurrence.

‡ That such cannot take place in Man, is due not merely to the far less complete adapta-
on of his skin for the aeration of the blood, but also to the difference in the type of his
rculation, which causes the arrest of blood in the pulmonary vessels to produce a stagnation
f the entire current.

due to failure in the propulsive power of the Heart, which constitutes *Syncope.* This failure may occur either (*a*) in consequence of a loss of the proper irritability of the Muscular tissue, or (*b*) through the supervention of a 'tonic spasm,' the organ remaining rigidly contracted without its usual alternation of relaxation. The phenomena attending death in the two cases are not dissimilar, when the loss of irritability is sudden and immediate (as when it arises from violent impressions on the nervous system); for the individual suddenly turns pale, falls back or drops down, and expires with one gasp. But under the former condition, the heart is found *flabby,* sometimes empty, sometimes distended with blood, both cavities being equally filled; whilst in the latter, the heart is contracted and hard, containing little or no blood, as when in the state of *rigor mortis* (§ 335). — The cause of the loss of irritability, when sudden, usually lies in the influence of a 'shock' transmitted through the Nervous system, and originating either in some severe lesion of its central organs or of its peripheral expansion (§ 321), or in a deficiency of its supply of blood or diminution of its usual pressure (such as is produced by rapid detraction of blood, especially in the erect posture, by the rapid removal of the fluid in ascites without the substitution of artificial pressure, or by suddenly rising into the erect posture after prolonged recumbency,* still more, after long stooping), or in some powerful mental emotion, either exciting or depressing. A more gradual effect of the same kind is produced by lesions of the internal organs (such as rupture of the uterus), which often prove fatal by the general 'collapse' thus induced, rather than by the disturbance which takes place in their own proper functions; and this seems to be the usual *modus operandi* of corrosive poisons, whose effect upon the heart's action resembles that produced by severe burns of the surface in children. The influence of the proper *sedative* poisons, however, — such as digitalis, tobacco, aconite, and upas, — seems to be directly exerted, through the blood, upon the tissue of the heart itself; and the same is probably the case with some of those 'morbid poisons,' whose introduction into the system gives rise to diseases of the most intensely adynamic type, such as Malignant Cholera, in which the 'collapse' is out of all proportion to any local lesion. But again, the loss of the Heart's irritability may be a gradual process, resulting from the deterioration of its tissue by fatty degeneration or by simple atrophy; and this last condition may be due to deficiency of blood, as happens in chronic starvation and diseases of exhaustion, in which the failure of the circulation seems due to the weakening of the heart's power and to the lowering of the quantity and quality of the blood, as concurrent causes, the condition thus induced being appropriately designated *Asthenia.* In all cases it is to be observed, that when the Vital powers have been previously depressed, a much slighter impression on the Nervous system is adequate to produce Syncope, than would be required when it is in a state of full vigour.—The causes of the tonic spasm of the heart have not been clearly made-out, but it seems producible, like the more common form of Syncope, by agencies operating through the Nervous system; thus it has

* Hence it is that great caution should be exercised, in allowing patients who are convalescent from acute diseases to rise into the erect position; many cases of fatal syncope having been thus induced. The state of general debility, and the continued recumbency, both favour this result; especially in persons advanced in life.

ıpervened upon the ingestion of a large quantity of cold water into the .omach.

1067. Somatic Death may be occasioned, *secondly*, by an obstruction to ıe flow of blood through the capillaries of the lungs, constituting *Asphyxia* (§ 574); and this may be consequent upon a disordered state of the lungs ıemselves, or upon suspension of the respiratory movements through affec-ions of the Nervous centres. It is in this mode that most fatal disorders f the Nervous System produce death, except when a sudden and violent npression occasions a cessation of the heart's power; thus in Apoplexy, Narcotic Poisoning, &c., death results from the paralyzed condition of he Medulla Oblongata; whilst in Convulsive diseases, the fatal result nsues upon a spasmodic fixation of the respiratory muscles.—*Thirdly*, Somatic death may be occasioned by a disordered condition of the *Blood* itself (§ 178), which at the same time weakens the power of the Heart, mpairs the activity of the Nervous system, and prevents the perform-ance of those changes in the systemic Capillaries, which afford a powerful auxiliary to the circulation. This is Death by *Necræmia.**—*Fourthly*, Somatic death may result directly from the agency of *Cold*, which stag-nates *all* the vital operations of the system. Where the cooling is due to the agency of an extremely low external temperature, which acts first upon the superficial parts, there is reason to think that the congestion of the internal vessels thereby induced, occasions a torpid condition of the Nervous centres, and that the cessation of the Circulation is immediately due to Asphyxia. But when the cooling is gradual, and the loss of heat is almost equally rapid throughout, it is obvious that the stagnation must be universal, and that no cessation of activity in any one part is the occasion of the torpor in the functions of the remainder. It is in this manner that death results from Starvation, and not by the weaken-ing of the heart's action, as commonly supposed; the proofs of this have been already stated (§ 658). And as a general rule we find, that the more active the changes which normally take place in any tissue during life, the more speedily does its Molecular Death follow Somatic Death, the requisite conditions of its vital action being no longer supplied to it. Thus we observe that, in Cold-blooded animals, the supervention of Mole-cular upon Somatic death, is much less speedy than it is in Birds and Mammals. This seems due to two causes. In the first place, the tissues of the former, being at all times possessed of a lower degree of vital activity than those of the latter, are disposed to retain it for a longer time; according to the principle already laid down. And, secondly, as the maintenance of a high temperature is an essential condition of the vital activity of the tissues of warm-blooded animals, the rapid cooling of the body after Somatic death is calculated to extinguish it speedily; and that this cause has a real operation, is evinced by the influence of artifi-cial warmth in sustaining the vital properties of separated parts.—The rapidity with which Molecular death follows the cessation of the general circulation, will be influenced by a variety of causes; but especially by the degree in which the condition of the solids and fluids of the body has been impaired by the mode of death. Thus in Necræmia, Asthenia, and death by gradual cooling, Molecular and Somatic death may be said to be

* See Dr. C. J. B. Williams's "Principles of Medicine," 2nd edit., p. 464.

simultaneous; and the same appears to be true of death by sudden and violent impressions on the Nervous system (§ 321). But in many cases of death by causes which operate by producing a more gradual Syncope or Asphyxia, the tissues and blood having been previously in a healthy condition, Molecular death may be long postponed; and we cannot be quite certain that it has supervened, until signs of actual decomposition present themselves.—When Molecular death takes place in an isolated part, it must result from some condition peculiar to that part, and not primarily affecting the body in general. Thus we may have Gangrene or Mortification of a limb as a direct result of the application of severe cold, or of an agent capable of producing chemical changes in its substance, or of violent contusions occasioning mechanical injury; or, again, from an interruption to the current of nutritive fluid; or, further, from some ill-understood stagnation of the nutritive process, which manifests itself in the spontaneous death of the tissues without any assignable cause, as in some cases of senile gangrene. Sometimes we are enabled to trace this stagnation to a disordered condition of the circulating fluid; as in the gangrene resulting from the continued use of the ergot of rye or wheat; but we can give no other account of the almost invariable commencement of such gangrene in the extremities, than we can of the selection of lead, introduced into the blood, by the extensors of the fore-arm.—When Mortification or Molecular Death is once established in any part, it tends to spread, both to contiguous and to distant portions of the body. Thus we have continually to witness the extension of gangrene of the lower extremities, resulting from severe injury or from the use of the ergot, from the small part first affected, until the whole limb is involved; and this extension is easily accounted-for, by our knowledge of the tendency of organic substances in the act of decomposition, to produce a similar change in other organic substances subjected to the influence of proximity to them. And the propagation of the gangrenous tendency to remoter parts, is obviously due to the perversion of the qualities of the Blood, which results from a similar cause.*

1068. It is quite certain that an *apparent* cessation of *all* the vital functions may take place, without that entire loss of vitality which would leave the organism in the condition of a *dead* body, liable to be speedily disintegrated by the operation of chemical and physical agencies (§ 115). The state of Syncope is sometimes so complete, that the heart's action cannot be perceived, nor any respiratory movements be observed, all consciousness and power of movement being at the same time abolished; and yet recovery has spontaneously taken place, which could scarcely be the case, however, if *all* vital action had been suspended. It is not a little remarkable, that certain individuals have possessed the power of *voluntarily* inducing this condition. The best-authenticated case of this kind is that of Col. Townsend, which was described by Dr. George Cheyne,† who was himself the witness of the fact. But statements have been recently made respecting the performances of certain Indian Fakeers, which are far

* On the proximate causes of Death, see especially the Art. 'Death,' by Dr. Symonds, in the "Cyclop. of Anat. and Phys.," vol. i.; the first chapter of Prof. Alison's "Outlines of Pathology and Practice of Medicine," and Dr. C. J. B. Williams's "Principles of Medicine," 2nd edit., pp. 452–469.

† See his "Treatise on Nervous Diseases," p. 307.

more extraordinary; it being demonstrated, if these assertions are to be credited,* that the Human organism may not only be voluntarily reduced to a state resembling profound collapse, in which there appears to be a nearly complete suspension of all its vital operations, but may continue in that condition for some days or even weeks,—until, in fact, means are taken to produce resuscitation.—Another form of apparent death, the existence of which appears to be well-authenticated, is that sometimes designated as 'Trance' or 'Catalepsy,' in which there is a reduction of all the Organic Functions to an extremely low ebb, but in which Consciousness is still preserved, whilst the power of voluntary movement is suspended; so that the patient, though fully aware of all that is being said and done around, is unable to make the least visible or audible sign of life.† It is impossible, in the present state of our knowledge, to give any satisfactory account of these states; but some light appears to be thrown upon them by certain phenomena of Artificial Somnambulism, 'hypnotic' or 'mesmeric' (§ 827); for in this condition, there is sometimes an extraordinary retardation of the respiratory movements and of the pulsations of the heart, which, if carried further, would produce a state of complete collapse; and its self-induction is suspected by Mr. Braid to be the secret of the performance of the Indian Fakeers just referred-to.

1069. The signs by which *real* is certainly distinguishable from *apparent* Death, are not numerous, a large proportion of those commonly relied-on being fallacious; but they are conclusive.—In the first place, it is to be remarked that no reliance is to be placed, for the reasons already mentioned, upon the apparent cessation of the Heart's action and of the Respiratory movements; since the reduction of these to so low a condition that they are no longer distinguishable, is by no means incompatible with the persistence of vitality. A surer test, however, is afforded by the condition of the *Muscular* substance; for this gradually loses its irritability, after real Death, so that it can no longer be excited to contraction by

* See a collection of these cases, directly obtained from British officers who had been eye-witnesses of them in India, by Mr. Braid, in his "Observations on Trance, or Human Hybernation," 1850.—In one of these, vouched-for by Sir Claude M. Wade (formerly Political agent at the Court of Runjeet Singh), the Fakeer was buried in an underground cell, under strict guardianship, for *six weeks;* the body had been twice dug up by Runjeet Singh during the period of interment, and had been found in the same position as when first buried. —In another case, narrated by Lieut. A. Boileau, in his "Narrative of a Journey in Rajwarra, in 1835," the man had been buried for ten days, in a grave lined with masonry and covered with large slabs of stone, and strictly guarded; and he assured Lieut. B. that he was ready to submit to an interment of a twelve months' duration, if desired.—In a third case narrated by Mr. Braid, the trial was made under the direct superintendence of a British Officer, a period of nine days having been stipulated-for on the part of the devotee; but this was shortened to three at the desire of the Officer, who feared lest he should incur blame if the result was fatal.—The appearance of the body when first disinterred, is described in all instances as having been quite corpse-like, and no pulsation could be detected at the heart or in the arteries; the means of restoration employed were chiefly warmth to the vertex, and friction to the body and limbs.—It may be remarked that the possibility of the protraction of such a state (supposing that no deception vitiates the authenticity of the narratives referred-to) can be much better comprehended as occurring in India, than as taking place in this country; since the warmth of the tropical atmosphere and soil would prevent any serious loss of heat, such as must soon occur in a colder climate, when the processes whereby it is generated are brought to a stand.

† Several such cases are recorded in Dr. H. Mayo's "Letters on the Truths contained in Popular Superstitions," and also by Mr. Braid, Op. cit.

electrical or any other kind of stimulation; and the loss of irritability is succeeded by the appearance of cadaveric rigidity (§ 333). So long, then, as the muscle retains its irritability and remains free from rigidity, so long we may say with certainty that it is not dead; and the persistence of its vitality for an unusual period, affords a presumption in favour of the continuance of some degree of vital action in the body generally; whilst, on the other hand, the entire loss of irritability, and the supervention of rigidity, afford conclusive evidence that death has occurred. The most satisfactory proof, however, is given by the occurrence of *putrefaction;* this usually first manifests itself in the blue-green coloration of the cutaneous surface, especially the abdominal; but it speedily becomes apparent in other parts, its rate being usually in some degree of accordance with the external temperature, though also much influenced by the previous condition of the solids and fluids of the body, these having been sometimes left by diseased actions in a state that renders them peculiarly prone to disintegration (§ 418).

1070. With the final restoration of the components of the Human Organism to the Inorganic Universe, in those very forms, or nearly so, in which they were first withdrawn from it, the Corporeal Life of Man, of which it has been the object of the foregoing Treatise to sketch the leading features, comes to a final close. But the Death of this Body is but the commencement of a new Life of the Soul; in which (as the religious physiologist delights to believe) all that is pure and noble in Man's nature will be refined, elevated, and progressively advanced towards perfection; whilst all that is carnal, selfish, and degrading, will be eliminated by the purifying processes to which each individual must be subjected, before Sin can be entirely subjugated, and Death can be completely "swallowed up of Victory."

# INDEX OF SUBJECTS.

B.

C.

D.

E.

## I.



## J.

K.



L.

## M.

N.

O.



P.

S.

T.

W.

# INDEX OF AUTHORS REFERRED-TO.

E.



F.

J.



K.

L.

## M.

THE END.

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